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Squeeze Film Damper for Mechanical Systems – A Review

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Abstract—*This paper, presents an overview of design and modeling of squeeze film damper, in term of various concepts of squeeze film damper (SFD) design, flow Patten of lubricant, arrange of lubrication hole location and different modeling techniques and also discuss the various type of lubricant oil with different stiffness and viscosity and the operating parameter of SFD in the presence of excessive lubricant suppler or multi direction lubricant supply and use of magneto rheological fluid squeeze film damper and SFD reviewed In all the analytical ,computational and experimental aspects.*

Keywords: *Design review, modeling review, squeeze film damper, viscosity of lubricant.*

1. Introduction

Squeeze film damper (SFD) has vibration reducing properties mostly when engine run with critical speeds, squeeze film damper was developed in the 1960 and it was widely used in aircraft engines. in the end of 1970s the SFD were retro fitted in high pressure multistage centrifugal compressor, [57].SFD has capability to reduce the vibration amplitude, that is why is extensively used for high speed operation in turbo machines as a result less force transmitted to the structure frame [58].when we tilt closely put flat plates and then more them in axial motion, surface film is produced in the fluid. it results the viscosity of the fluid in the damper for certain range of operation, [59] SFD is satisfy the modern need of bearing operation under lubrication high speed, small frictional torque under extreme temperature environments, [60] ,use of non-Newtonian fluid like MR fluid use as semi active fluid for control the vibration , caused by rotation of shaft ,[1] and design and modeling for high Reynolds no up to 13 obtain with eccentricity ratio.0.2,0.5 and 0.8 and also explain the large fluid inertia force based damper, [7] using high-speed motion video and picture recording, the true different geometries were limited up to 5000 rpm due to clarity of the photo received at the lower speeds [9]. the fluid film pressure which is used in SFD for finite squeeze film damper is lower than the rupture pressure of liquid film because after rupture nook is created by using of Jakobossen- Floberg-Olsson (JFO) to find the extent of cavitations region but this model is difficult in practical application [13].the theoretical and experimental studies an squeeze film damper for reducing the amplitude of vibration by using two ball bearing based stabilizers has been used and also test the different sample of Newtonian and viscoelastic lubricant in to the SFD to analyze the level of high amplitude vibration at high speed rotor, [16] for short cylindrical squeeze film dampers when works at large value of eccentricity ratio convective inertia terms are important[61]. Herschel-Bulkley fluid (plasticine) are use for examine the theory of lubrication in details with squeeze film damper[25].The new model short SFD analyze for fluid forces and also explain the effect of damping factor for fluid inertia for 2π film [22].when increases the circumferential feeding groove in SFDs than we see more orbit radius of rotor unbalance and whirling for rigid rotor response[29],[32].The analyses of grooved squeeze film damper par the Reynolds numbers less than 1 has been done for un cavitated lubricant conditions and also find out the radial forces for substantial magnitude [62].The numerical method for analyses of rotating shaft in the squeeze film damper are explained and also explain the harmonic numerical balanced technique for prediction of steady state response for both sub harmonic and super harmonic component [34].The response of frequency is highly dependent of the unbalanced and stiffness and also explain how the parameters is selected to avoid excessive vibrations [37].Influence of and seal clearance of circular orbiting SFD with a central circumferential feed groove and analyzed and effect of groove explain with the help of analytical modeling[38].Derive the equation of the SFD of flexible rotor with retainer spring and without retainer spring and examine the concentric and eccentric response of damper of both the cases and see at lower frequencies use of centralizing Spring in SFD is more prone to reduce vibration signal [40],[10].Theory for designing the grove two land and modeled and very shallow grooved of SFD is explain for designing the [33].The bifurcation response of rotors which is supported by cavitated squeeze film damper is more effective for controlling the non synsynchronous and chaotic motion by introducing the cyclic stress in the rotor[14].Design and operating parameter of high speed rotor response in SFDs without using centering springs has been examined effectively using direct numerical integration [42-43].By using different material of damper and apply different lubrication process found the natural frequency and test like

different parameter, displacement, eccentricity ratio with the help of modeling CATIA software and fabricated the test rig [46].here explain the effect of rotating high speed rotor in the SFD with two method , saddle- node and Hopf bifurcation[63].use of Magneto rheological fluid (MRF) by blending quasi Newtonian for low sheer stress and harschel- bulkaly models for high shear stress analyze for see the suspension behavior of SFD[2] . damping of air gaps is studies for micromechanical squeeze film damper By using FEM software for modeling and Nervier stokes equation for analytically[47].For providing additional damping here use of retainer springs squeeze film damper for flexible rotor and analyze the effect of design parameters like gravity, mass ratio, stiffness ratio [44]. For calculating the various parameter like damping forces and stiffness after applying the different boundary condition by applying green's function [48]. The paper introduce to recognize finite difference (FD) solution of the in compressive Reynolds equation by using chehyshev polynomial fits. [41].in SFD use to introducing the lubricant with couple stress fluid and stability the derivative controller for stability the rotor bearing system[8].Cross coupled and direct coefficients are derived for the film (π and 2π) Gumbel cavitations condition and homogeneous two phase mixture using in a SFD and CFD-ACET act commercial software has used to analyze the relation mathematically [40]. New formula introduced of Reynolds nonlinear equation for the evolution of pressure inside the squeeze film damper including the effect of air [35].Use of air between the two plate designs and derived from CFX and FEA of a general bearing based squeeze film damper [26]. The experiment has done on SFD by using air channels in large sensing parallel plate for reducing damping coefficient by using MEMS with air channels in parallel plates[27].the methodical analysis of the active behavior of a gear bearing system with PSED under non linear suspension [24].The validation and introduction of non linear squeeze film damper by using the neural network technique obtained from experimental result to reproduce the output- input function for the complete range of the squeeze film damper clearance [18].turbine generator to unbalance force produced by mass of the system.[49].an rigid rotor SFD system the bifurcation behavior play important role for considering the fluied inertia effect. [30].Studying the squeeze film damper on behaviors on higher order higher frequency resonant code of resonators show high class and several mode up to 16Mhz [36].Twin shaft test ring both are unbalance rotor are nonlinear coupled and both has to hold on SFD bearing support like a real air craft engine for analysis the overall vibration response[19].Flexible rotor brings system contained large clearance ends SFD having a central feed groove [15].by using bifurcation analyses and assuming speed parameter for the rotors. [64].the selection of SFD[24].for controlling the unwanted vibration introduce the Novel active squeeze film damper by using the magnetic bearing [65].using MR magneto rheological fluid based damper for reducing the lateral vibration and introduced the mathematical model [4]. this paper introduce about the design about of SFD for this speed rotor by provide centralizing spring [66].Design and develop of SFD for high speed machinery for reducing unwanted vibration for the following parameter like damping ratio logarithmic development at transmissibility [20].Two lobe squeeze film damper for rigid rotors on analysis of shape parameters ,wave profile related to the damper bearing [12].Controlling the magnetic induction speed the MR SFD by 2D, 3D FBM software [6].a comprehensive and thorough review is required for significant development &research of SFD this paper explores advancements in formulas ,modeling & design. The review starts with concise exploration of operation modes which is followed by categorization of SFDs and the modeling techniques.

2. Operational technique of SFD

In this context .we are discussing about different method of operation of fluid (lubricant) which is used in squeeze film damper.

2.1 Application for active control of vibrations in mechanical system, magneto rheological fluid based SFD the geometry of possible application of MR damper shown in Figure 1 [1].

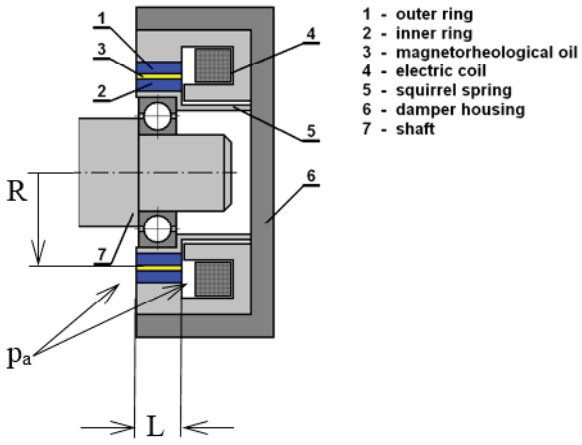


Figure 1: Geometry of squeeze film damper [1]

The electric current in the coil which generated magnetic induction, controls the magnitude of viscosity [1]-[6]. The analyses of squeeze film for parallel lateens lubrication analyses for Hershel- Bulklay fluid flow with in conditions of no slip wall boundary given the following equation which is used for general gap profile between the platens h = ***h(r)*** between the platens [7-8].

$$\frac{n+1}{n}\left(\frac{r}{R}\right)SX^2 - \frac{n+1}{2n+1}(-X-1)^{(2n+1)/n} - (-X-1)^{(n+1)/n} = 0,$$

r- radial coordinate. X- dimensionless pressure gradient.

This expression also uses a spherical and planar platen.

For a big radius of curvature in spherical geometry against a planar platen the gap h=h(r) approximated by parabolic relations[9-10]for experiments where material plasticine is homogenized in a z-blade mixer prepared a disc about 50mm dia and 3 mm thickness. orifice flow and plastometer has used for the measurement of orifice flows the dia of ram of equipment 64 mm and the dia of orifices 1-4mm has employed [9-11].

2.2 THE EFFECT OF FLUID INERTIA

Fluid inertia has been studied as a problem among many interrelated problems for calculating the fluid inertia effect the situation has set -up eventually resolved. This shaft set-up which can be removed when outer ring alignment to the outer ring.[12-13]

2.3 CAVITATING SFD

The study of cavitations using high speed motion picture has helped in controlling orbit. SFD is designed to accommodate a different range of damper feed configurations. The test rig is shown in the Figure 2 [14].

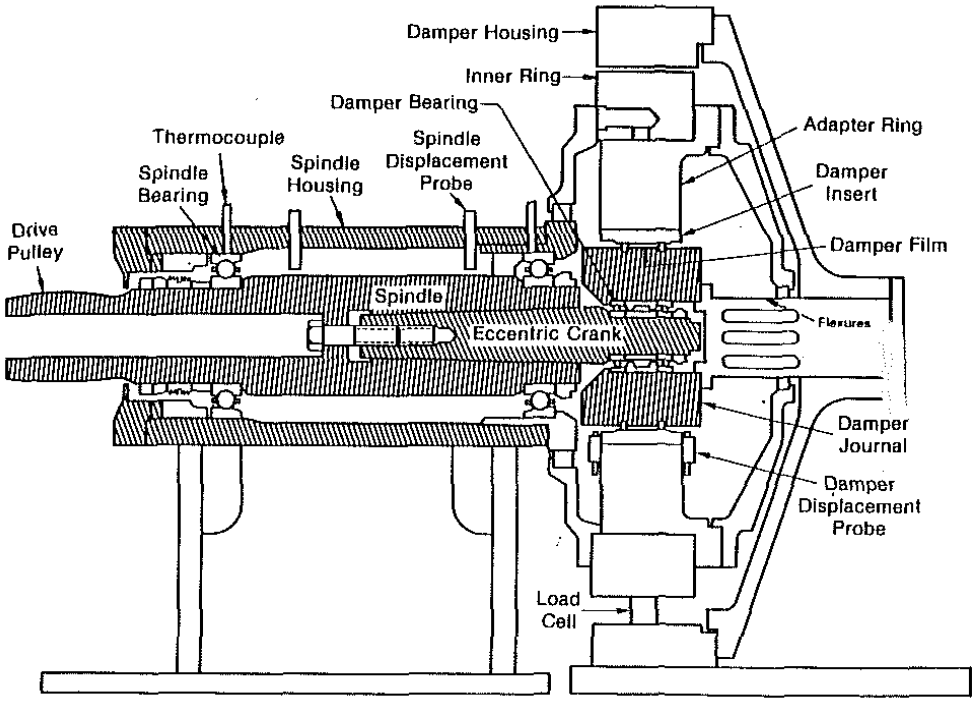


Figure 2: Test rig of controlled orbit.[14]

1. Al Hole feed damper journals with a land length 2.54-cm and 126.59mm diameters.

2. The backup ring made up of with Solid aluminum.

3. Al acrylic damper with inside diameter of a 127.0-mm.

A detail description of the analyses used for comparisons with the groove damper sealed geometry tested [15-18]. SFD bearing having two open ends and the outer ring is fixed. Thin annulus is filled with lubricant and the cylinders are aligned [19-22].

2.4 SFD stabilizers for flexible rotor using different lubricants.

For controlling the vibration of high speed rotating shaft there are two set of ball bearing has been used as a stabilizers and a journal bearing, and SFD data has been taken by using the different sample of lubricants the lubricants sample prepared with some Newtonian fluid and combined with some viscoelastic lubricants. Test the vibration level at high speed by using different sample in two ball bearings SFD the set up like Figure 3 [23]

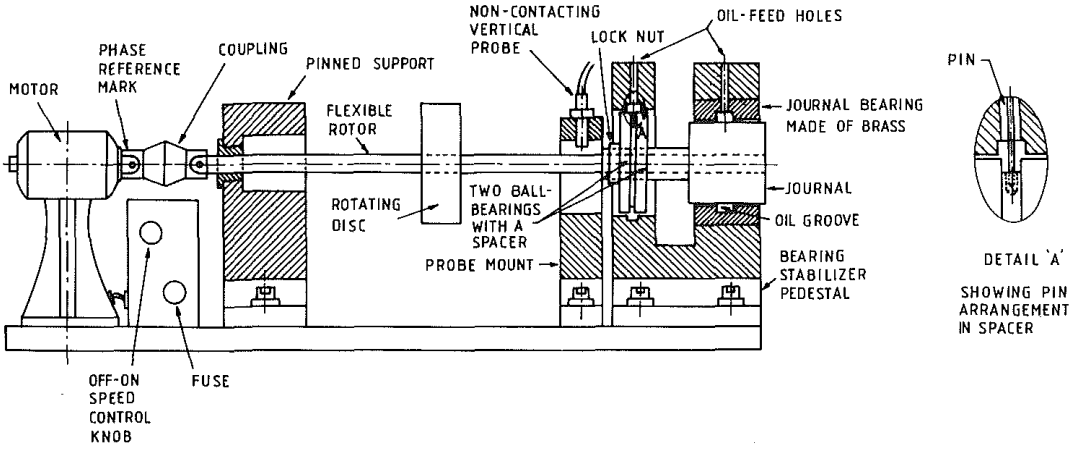


Figure 3: Flexible rotor set up with stabilizers. [23]

Journal bearing and stabilizers have been lubricated by gravity method [24-28].

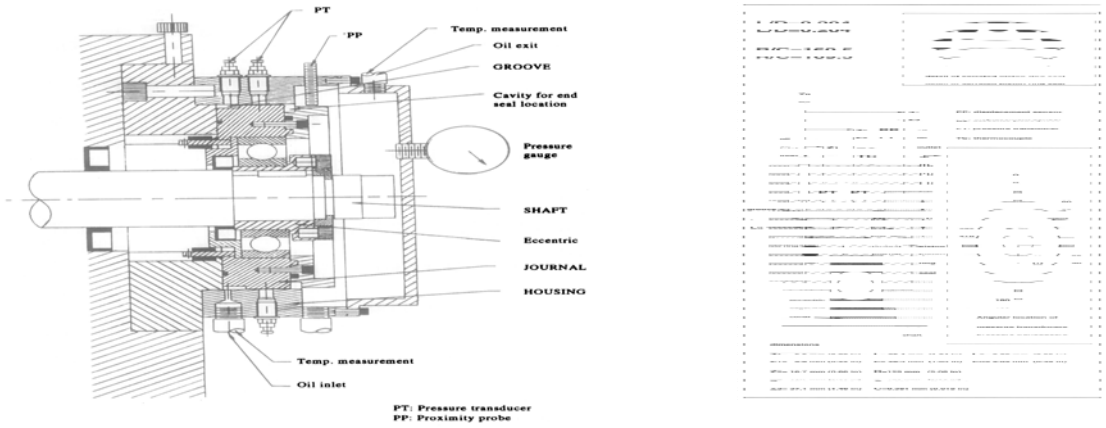
2.5 Squeeze film dampers with short cylinders

Analyzed the theoretical work and compared it with published work and compared the experimental work with non linear cylindrical SFD. For this, two models have been used.

2.5.1 Gradient model of Pressure - For two dimension flow in the y-z plane in Cartesian coordinates the general N-S equations have been simplified using reasoning of border magnitude e.g, Szeri et al. [29]. This equation fairly represents the conditions present in short cylindrical SFSs ,where y and z denote the two radial and axial directions. The fluid forces on the journal of cylindrical squeeze film dampers after integrating the pressure gradient expressions [30-33]

2.6 Method of feeding groove of fluid on SFD

Under the fluid inertia the effect of circumferential groove feeding on unbalance reaction of the rotor has been analyzed with the rotor system performance within certain assumptions. Rotor may be subjected to external loads of synchronous rotor. Rotor is rigid and the rolling element bearing is rigid radically and constant speed [34-35, 37-38]. Here open and sealed damper configuration is tested under the test rig (ref. Figure 4(a)) [36]. Front axial view of test section of the damper and position of instruments (ref. Figure 4(b)) [36].



(a) **(b)**

Figure 4: (a) SFD Test-rig [36] (b) Damper test section with location of instruments [36]

2.7 Method of efficient computation and nonlinear response in SFD of rotating part.

In this paper the theoretical Reynolds equation of basic oil film lubrication for squeeze film has been explained and derives the relation of squeeze film in the term of Reynolds equation [39]. Also use the different numerical tool like fast numerical method, Ranga-Kutta method for first four periods, Fast integration method also used for calculate the equation numerically and use the method of simple iteration but the method of Ranga-Kutta and the method of fast integration accurately predict the steady state and transits' response for a system of using different condition like eccentric motion and supply pressure and but the method is time consuming for less time consumption use method of simple iteration & harmonic balance [40-42].

2.8 SFD on Floating Ring

The analysis of test rig has been published under the following theory.

A) General theory – for one of more SFD flexible supports equation of vibration for force and mass for avoid more computation time the equilibrium or steady state solutions of non linear derive.

B) Dynamic modeling-in this theory modeling of floating ring squeeze film damper through the general equation of vibration of damper, mass and force [43].

For obtaining stable equilibrium solution of the technique [44], the effect of side clearance of SFD performance by using theoretical consideration using Navier-Stokes equation and computational approach by CFD codes [45-46].

Analysis of damping capacity of SFD for reducing the vibration of flexible rotors has been used two model.-mathematical model, experimental model, on the test rig the following measurement have been calculated – displacement, SFD geometry, Natural frequencies [47] , mathematical model produce their matrix of the different condition [48].

2.9 Bifurcation response in SFD of a rotor

Bifurcation of a rotor response in SFD with the application of centering spring, here two type of SFD with and without centering springs has been explained (ref. Figure 5) [49]

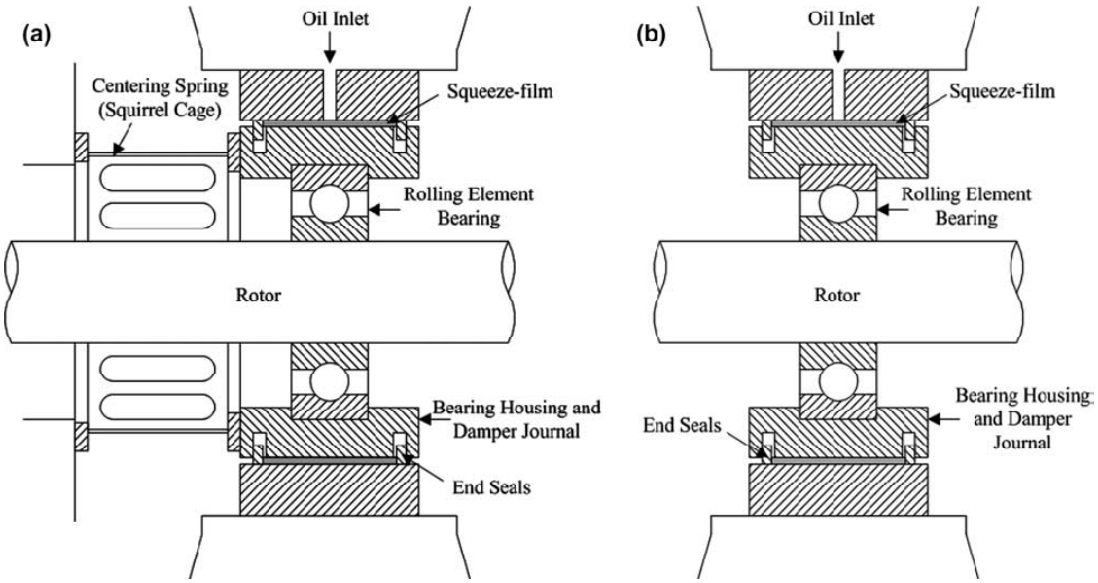


Figure 5: (a) SFD inbuilt centering springs (b) SFD absence of centering springs [49]

Formulation of equation of motion for the above said condition with the following assumptions [49].

(a) The rotor, having some part of its mass collected of the rotor at the mid-span and rest part of the mass at bearing stations, having symmetric.

(b) Speed of the rotor is constant.

(c) The stiffness of the rotor and support are radically symmetric.

(d) The damping force, due to air dynamics on the disc put on mid-span of the rotor is viscous

(e) All the rotor mid span on the disc, in balance is finding in single plain.

(f) Due to rigidness of the rolling element bearing denote create excitation force.

(g) Gyroscopic effect can be neglected.

And study the different graph place with times series, rotor whirl orbit, power spectrum [49].

Transition to chaos in SFD both condition with centralizing spring and without centralizing spring with the help of formula of governing equations [50-52].

2.10 Different material used in SFD.

In this paper prepare the two type of damper of material taflon and steel for analysis the flexible rotor with the help of FEM software & on the test rig with the help of DASY lab software for data acquisition [53].

2.11 Modelling of trapped gas in micromechanical SFD.

Viscoelastic wave propagation model studies with respect to following parameter(a) variables, damping and spring forces characteristic numbers and lineaized Navier -Stokes equations.(b) wave propagation model here simple solution, resonant frequencies[54].

2.12 Modelling of SFD using green function for rectangular elastic plates.

Squeeze film analysis for rectangular elastic plates shown that the fluid flow in is governed by the navies stokes momentum equations and continuity equation .under this assumption, there is a small gap of air between the two plates of SFD flow is 2-D [55]. a dynamic model of squeeze film force with the help of Reynolds equation of pressure distributions ,firstly calculate the squeeze film forces and then dynamic model formulation with the help of turbine generator data.[56]

3. Discussion

Although there have been so many achievements in creating various designs of squeeze film damper in the last four decades, still there is need for efforts to increase to increase the effectiveness of SFD in the operation of high speed rotors according to [1] magneto rheological fluid has been used for active control of vibrations there are many papers [1-6] discuss about magnetic induction in the application of MR fluid based damper ,from [7-8] equation for Hershel-Bulklay fluid has been derived for the analyses of squeeze film in parallel lateens of lubrications [9-10] geometry of large radius curvature derive under various thickness of fluid film [12-13] the inertia effect of fluid studies in different SFDs [14] the effect of cavitations of high speed rotor under a wide range of different damper feed [15-18] a brief description of analyses of sealed grooved damper,[19-22] SFD with both of ends open and outer ring is fixed has been studies,[23-28]using the different sample of Newtonian & visco elastic lubricant in SFDs studies through experiment set-up and bond graph modeling [30-33] neiver stokes equation for 2-D flow in y-z plane derive, [34-35] the experimental studies on SFD on rolling elements bearing at constant speed,[39] derive the relation of squeeze film in the term of Reynolds equations.[40-42] different numerical method has been derive for the analyses of SFD.[43] floating ring squeeze film damper theoretically analyses and tested under two different theory (1) general theory(2) dynamic modeling, [47] analyses of damping capacity of SFDs for reducing the vibration of flexible rotors,[48] produce the mathematical model for different condition of operation.[49] application of centering springs has been verified ,[53] in this paper different material used in SFD using FEM software ,[55]lubricant film analyses for rectangular elastic plates the flow of the fluid in continuum regime is governed by navies stokes momentum equations and continuity equations.

4. Conclusions

In this paper, various designs of SFDs have been presented and their categorization is done based on the flow flow pattern of lubricant ,arrangement of lubricant hole position, MR fluid squeeze film damper, cavitating squeeze film damper and the different type of mathematical modeling as well as softare modeling like ,Bond Graph, FEM and SYMBOLS 2000,how ever the different type of SFD is studies in the application of mechanical systems for active control of vibrations effect of fluid inertia ,cavitating squeeze film, stabilizers based SFDs, short cylinder squeeze type, feeding groove of lubricant fluid, study of an nonlinear response in SFDs of rotating part, floating ring squeeze film ,bifurcation of a rotor response in SFD, material used in SFDs modeling of trapped gas in MEMS AND modeling of rectangular elastic plates using green function but there is still need to develop the high speed high performance, long lasting squeeze film damper with low maintenance.

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