Mechanical Engineering Department
Texas A&M University

2012/2013
Research Progress Report
Tribology Group

Year XXII

33nd Annual
Turbomachinery Research Consortium Meeting

May 2013

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http://rotorlab.tamu.edu

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FOREWORD

Thanks for your support during the past year. Students and I have worked very hard to deliver promised work and to learn in the process. Alas, it is not always easy. I am already exhausted having to beg for things to be done, constantly reminding students about the importance of hard work, discipline, integrity and respect as virtues that build character and enable professional success. I am already too old and frail, without a doubt I've lost my *mojo* having to handle, day after day, perennial teenagers with very different cultural values.

The new Millennium students are less and less prepared to undertake independent work, do not know how to exercise critical thinking, and they only *phish* & *google*. Libraries are architectural marvels with a forgotten arcane purpose. In a virtual world, knowledge is also virtual, ephemeral. If *google* does not show knowledge, it doe not exist. If *google* finds related knowledge, ipso facto becomes an article of faith, unquestionable. Life BG and AG (before and after google). There is so much information at our fingertips and so little time to spare as we text, twitter, google, spam, and swipe over apps….

Texas A&M continues on its path of transformation. Please visit http://engineering.tamu.edu/25by25 to learn about a bold plan: to double our number of engineering students to 25,000 by 2025. We will do this without requesting more resources from the state, taxing the students (increasing tuition and fees), without hiring more faculty, and in actuality, reducing the class sizes! In the Fall 2013, Mechanical Engineering will begin to deliver (a much needed) distance learning Master of Engineering Program. I will debut the program teaching Vibrations. I have a couple of months to figure out the best way to deliver a course and to keep faceless students (practicing engineers) engaged after their work hours. The MOOCs[1] are coming and will change forever the traditional way education is delivered!

Prof. Andreas Poycarpou is our new ME Department Head. He is a well known tribologist from the University of Illinois-UC. Andreas is doing a good job; everyone is helping to keep us afloat with a number of requests from the upper administration. It seems we are parked indefinitely in the emergency quadrant! I chair too many committees and must attend to too many meetings at the department, college and university levels. Worthy of note, I chair a Committee on Climate, in an attempt to warm up our freezing ME Department. Surveys show that ME ranks at the bottom in the University as a place that welcomes and promotes diversity.

Last June 2012, ASME IGTI Structures & Dynamics Committee recognized one of our papers as best. This year, in June 2013, ASME IGTI Structures & Dynamics and Microturbines Committees will recognize two papers as best, one on each track! Seven best paper awards in the last ten years; we (you and I) must be doing something right!

The list of funded projects in FY 2012-13follows:

- **Squeeze Film Damper – Identification of dynamic forced performance**
  OBJECTIVE: Experimental validation of novel SFD designs for aircraft applications.
  STATUS: Test rig operational (500 lbf dynamic force). Measurements and force coefficients identification completed in a 5" OD sealed ends SFDs.
  SPONSOR: PRATT & WHITNEY ENGINES, **$436,264** Project started January 1, 2010 (4 year).
  Students: Gary Bradley (M.S.), Jerry Haripin (U.G.)

- **Computational Model for Thrust Collars in Integrally Geared Compressors**
  OBJECTIVE: To improve design of thrust collars for IG Compressors.
  STATUS: Model for prediction of pressure field in thrust collar completed. Extensions to include thermal energy transport tp follows.
  SPONSOR: SAMSUNG TECHWIN, **$158,639** Project started September 1, 2012 (2 year).
  Students: Travis Cable (M.S.)

[1] MOOC: Massive Online Open Course

- **Squeeze Film Damper – Assessment of Linearized Force Coefficients Model**
  OBJECTIVE: To determine goodness of linear vs nonlinear SFD force models.
  STATUS: Force coefficients identified in a 5" OD open ends SFD with central groove. Fluid inertia dominates SFD forced response.
  SPONSOR: TURBOMACHINERY RESEARCH CONSORTIUM, **$65,578** Project started September 1, 2011 (2 years).
  Students: Sung-Hwa Jeung (M.S.)

- **Computational Model for Tilting Pad Journal Bearings**
  OBJECTIVE: Develop code for prediction of tilting pad bearings forced response accounting for thermal effects and including pivot flexibility and pad surface deformations.
  STATUS: XLTPJB©, benchmarked to test data, available to TRC users
  SPONSOR: TURBOMACHINERY RESEARCH CONSORTIUM, **$111,405** Project start September 1, 2010 (3 years).
  Student: Yingkun Li (M.S.)

- **Computational Model for Pocket Damper Seals**
  OBJECTIVE: Develop code for prediction of pocket damper seals and laby-brush seals
  STATUS: XLPDS© available to TRC users. Extensions to model fully partitioned pocket damper seals in progress.
  SPONSOR: TURBOMACHINERY RESEARCH CONSORTIUM, **$40,984** Project start September 1, 2011 (4 years).
  Student: Yingkun Li (M.S.)

- **Wet Seals for Subsea Compression Systems**
  OBJECTIVE: Assess experimentally dynamic forced performance of oil-in-air *wet* seal.
  STATUS: Test rig being revamped
  SPONSOR: TURBOMACHINERY RESEARCH CONSORTIUM, **$44,984** Project started Jan 1, 2013 (1 year).
  Student: Qing Liu (Ph.D.), Mathew Hilton UG)

- **Automated Analysis of $XLTRC^2$ Time Transient Responses in Nonlinear Rotor Bearing Systems**
  OBJECTIVE: Modeling of NL rotor-bearing systems and GUIs for data handling of $XLTRC^2$ nonlinear transient rotor response output data.
  STATUS: GUIs developed for automated analyses with minimum User interaction. Applications sought
  SPONSOR: TURBOMACHINERY RESEARCH CONSORTIUM, **$76,347** Project start May 1, 2011 (2 years).
  Student: Qing Liu (Ph.D.), Jieyun Zhang (M.S..)

- **Metal mesh foil bearings (MMFB) for high speed turbomachinery**
  OBJECTIVE: Continue to advance gas bearing technology for high temperature, high speed microturbomachinery applications (power < 400 kW).
  STATUS: Completed. Progress on measurement of structural stiffness of foil bearings with shims
  SPONSOR: TURBOMACHINERY RESEARCH CONSORTIUM, **$38,608** Project started Dec 1, 2011 (1 year).
  Student: Joshua Norsworthy (M.S.)

- **Turbocharger Nonlinear Rotordynamics**
  OBJECTIVE: Develop models for prediction of (semi) floating ring bearing forced performance and theit impact on the nonlinear rotor dynamics of turbochargers.
  STATUS: Code XLBRG_TH© completed in 2012. Will continue with NL rotor-bearing models
  SPONSOR : HONWYWELL TURBO TECHNOLOGIES. Funding since 2001.
  Student: (new) Xiaowan Shan (Ph.D.)

- **Computational Model for Textured Surface Gas Face Seals**
  OBJECTIVE: Develop code for leakage and forced response of textured gas face seals for steam turbines.
  STATUS: Code SpiralG extended to model T groove textured surfaces and GUI completed. Start Sept 1, 2011 – end w/o sight,
  SPONSOR : CIATEQ A.C. (MX),
  Student: Jose Hernandez (M.S. sponsored student)

Tuesday (12 pm) Time has run out and I am still half way…… Enjoy the meeting. We hope to count with your continued support in 2013-14.

Luis San Andrés, Mast-Childs Tribology Professor May 22, 2013

Tribology Group

Team Members 2012-2013

Name	Research project	Degree	Graduation date
Thomas Chirathadam Joshua Norsworthy Joshua Brooks*	Metal Mesh and Bump-type Foil Bearings: Identification of Rotordynamic Force Coefficients	Ph.D. M.S. B.S.	December 2012 May 2013 May 2012
Alain Anderson+	Measurement of leakage in a novel all metal non contacting annular seal at high temperatures	M.S.	August 2013
Travis Cable	Analysis of thrust collars for IGCs	M.S.	August 2014
Sung-Hwa Jeung Gary Bradley	SFD Test Rig & Measurements: Pratt & Whitney & TRC	M.S. M.S.	August 2013 August 2013
Feng Yu Xiaowan Shan	Nonlinear Rotordynamics of TCs and Bearing Code Development	M.S. Ph.D.	August 2013 August 2016
YuJiao Tao+ Yingkun Li	Computational Model for Tilting Pad Bearings	M.S. M.S.	December 2012 May 2014
Qing Liu+ Jieyun Zhang	Nonlinear Dynamics of Rotor-Bearing Systems	Ph.D. M.S.	August 2015 August 2014
Jose Hernandez+	Analysis of textured gas face seals	M.S.	December 2013
Weilian Shan	Analysis of pocket damper seals	M.S.	August 2014
Jerry Haripin* Mathew Hilton*	Experimental support to SFD and Wet Seal projects	B.S.	May 2014
	Visiting Scholars		Residence time
Dr. Sangshin Park	Yeungman University	S Korea	10 months
Takuya Kinoshita	Mitsubishi HI-Compressors	Japan	6 months
Andriy Zahorulko	Summy State University	Ukraine	3 months

(*) undergraduate student, (+) minority student (female, Hispanic, Asian, African-American)

(*) Tomas Chirathadam (SwRI), Alain Anderson (Halliburton) and Yujiao Tao (Samsung) not pictured. They are out in the real world making a difference!

2013 Research Progress Reports

Overdue from 2012
Automated Analysis of XLTRC^2 Time Transient Responses in Rotor Bearing Systems with Nonlinear Supports **TRC-RD-01-13** Qing Liu and Luis San Andrés
A Novel Computational Model for Tilting Pad Journal Bearings with Soft Pivot Stiffnesses **TRC-B&C-01-13** Yujiao Tao and Luis San Andrés
Gas Seal Leakage at High Temperature: a Labyrinth Seal and an All-Metal Compliant Seal of Similar Clearances **TRC-SEAL-01-13** Alain Anderson and Luis San Andrés
Metal Mesh Foil Bearings: Prediction and Measurement of Static and Dynamic Performance Characteristics **TRC-B&C-02-13** Thomas Chirathadam and Luis San Andrés
Currently funded projects (2012-2013)
A FE Model for Static Load in Tilting Pad Journal Bearings with Pad Flexibility **TRC-B&C-03-13** Yingkun Li and Luis San Andrés (available on June 1, 2013)
Identification of Structural Stiffness and Material Loss Factor in a Shimmed (Generation One) Bump-Type Foil Bearing **TRC-B&C-04-13** Joshua Norsworthy and Luis San Andrés
On the Forced Performance of an Squeeze Film Damper Operating with Large Amplitude Orbital Motions: Measurements and Assessment of the Accuracy of the Linearized Force Coefficients Model. **TRC-SFD-01-13** Seung-Hwa Jeung and Luis San Andrés
Predictions vs. Test Results for Leakage and Rotordynamic Force Coefficients of a Fully Partitioned Pocket Damper Seals and a Labyrinth Seal – Limitations of the Current Computational Model **TRC-SEAL-02-13** Welian Shan and Luis San Andrés

2013 RESEARCH PROPOSALS

CONTINUATION (NO FUNDING)	# years	Cost
AUTOMATED ANALYSIS OF TIME TRANSIENT RESPONSES IN NONLINEAR ROTOR BEARING SYSTEMS (YEAR III)	2	0
MAKING A WET (FOAMY) SEAL AND ESTIMATING ITS DYNAMIC FORCED COEFFICIENTS **(YEAR II)**	2	$ 0
CONTINUATION WITH FUNDING		
COMPUTATIONAL MODEL FOR TILTING PAD JOURNAL BEARINGS (YEAR IV)	4	$ 37,073
LINEAR-NONLINEAR FORCE COEFFICIENTS FOR SQUEEZE FILM DAMPERS (YEAR III)	3	$40,666
ENGINEERED ANALYSIS FOR POCKET DAMPER SEALS AND COMBINED LABYRINTH-BRUSH SEALS	2	$35,866
NEW **EFFECT OF SHIMMING ON THE ROTORDYNAMIC FORCE COEFFICIENTS OF A BUMP-TYPE FOIL BEARING**	1	37,996
NEW **THRUST BEARINGS A MODEL OR AN EXPERIMENTAL VERIFICATION – DECISION TIME**	2	$44,000

PROPOSALS –SUMMARIES

COMPUTATIONAL MODEL FOR TILTING PAD JOURNAL BEARINGS (YEAR IV)

Accurate prediction of the static and dynamic forced performance of tilting pad journal bearings is necessary to design, troubleshoot and predict the dynamic response and stability of rotor-bearing systems. Since 2010, the TRC funds the development of a computational tool for accurate prediction of tilting pad bearing force coefficients operating under heavy loads. In 2012, predictive tool XLTPJB®, including pivot flexibility, typically nonlinear, was delivered. In 2012, pad surface deformations due to mechanical pressures are accounted for by using an ANSYS® FE pad structure model. Correlations of predictions against test data for force coefficients is excellent provided the user knows a-priori the actual bearing/pad clearances at the operating temperature and has an accurate formulation, preferably empirical, for the pivot deformation. The specific tasks in 2013-14 are:

a) Validate the constructed pad FE structural surface deformation model with comparisons to archival data.
b) Develop an analysis including pad surface deformation for the prediction of frequency reduced TPJB rotordynamic force coefficients.
c) Construct a FE model that relates pad elastic deformations to thermally induced stresses, The process is more laborious than that for pressure induced deformations since the temperature field (**T**) does not only depend on the fraction of the mechanical energy from the shearing of the film conducted through the pad but also on the (unknown and often assumed) thermal boundary conditions on the sides and backs surface of a pad.

The enhanced computational program will enable TRC members to model commercial tilting pad journal bearing configurations. The tool will reduce the burden on the unseasoned user by calculating the actual operating clearances and reducing to a minimum the specification of empirical parameters and guessing the correct boundary conditions for a proper thermal analysis.

LINEAR-NONLINEAR FORCE COEFFICIENTS FOR SFDS (YEAR III)

Squeeze Film dampers (SFDs) aid to reduce rotor vibrations due to imbalance and other sources and also serve to isolate the rotor(s) from the engine frame or casing. Since 1990, the TRC sponsors a SFD research program with many practical advances derived from planned experiments and computational analyses. In 2012-2013, funding continued to produce force coefficients in an open ends SFD from large amplitude orbit amplitudes, centered and off-centered. For small to moderately large amplitude circular orbits, the direct damping and inertia coefficients show a greater dependency on the journal static eccentricity rather than on the journal whirl amplitude. For orbit radii exceeding 50% of the clearance, the added mass coefficients quickly vanish! Predictions from a physical model that includes the feed groove and adjacent film lands are in good agreement with the experimental force coefficients. In general, a linearized force coefficients model represents well the test SFD forces for operation with small to moderate static eccentricities, $e_s/c \leq 0.25$, and orbit radii $r/c \leq 0.40$.

Presently, OEMs are interested in ultra-short SFDs ($L/D<0.2$) to further save space and weight, shortening shafts in systems capable of withstanding large amplification factors (Q=25). Further, stringent operation demands of very light lubricants supplied at high temperatures to reduce contamination and fuel consumption. Aircraft engines need to endure sudden maneuver loads and must survive blade loss events. In large size grinding machines, SFDs are also used as cushions to quickly dissipate mechanical energy from sudden plunging motions when the tool contacts a work piece. These transient events may affect the integrity of the mechanical elements. In 2013-14 work is proposed to:

(a) Build and test a short length SFD (L/D=0.2) with a shaker inducing sudden loads (max. 400 lb_f) with motions as large as the film clearance. Linearized force coefficients may not represent best the forced performance of a SFD. Multiple load tests will evidence performance degradation versus the frequency of plunging motion.
(b) Build a computational physics tool to simulate the recorded SFD dynamic forced performance.

The proposed research is of interest for SFD applications in gas turbines, semi-floating ring bearings in turbochargers, hydrodynamic bearings in compressors, etc.

ENGINEERED ANALYSIS FOR POCKET DAMPER SEALS AND COMBINED LABYRINTH-BRUSH SEALS (YEAR II)

Parasitic secondary flows (seals leakage) in centrifugal compressors and turbines represent a substantial loss in efficiency and power delivery with an increase in specific fuel consumption. Pocket damper seals (PDS), which add radial baffles in (alternating) circumferential cavities of a labyrinth seal (LS), have demonstrated enormous benefits in seal stability by providing physically large damping coefficients. Analysis for fully partitioned pocket damper seals (FPDS) is presently lacking.

In 2012, the TRC funded a two-year project to develop a computational tool for accurate prediction of the forced response of PDSs. In 2013, GUI XLPDS© offers users a ready tool to run PDSEAL©, a 1999 tool for prediction of leakage and force coefficients in LSs and PDSss with sharp blades. Predictions for leakage, stiffness and damping coefficients correlate well with test data for a labyrinth seal. However, predictions are in gross error when compared to the experimental coefficients of a PFDS. Note that commercial FPDSs have thick walls rather than blades with sharp edges as in conventional LSs and early PDSs.

During 2013-14, the specific tasks are:

- Update the physical model for PDS by replacing the empirical leakage formulas with a bulk flow model that includes flow conservation and circumferential and axial momentum transport equations in the flow region under a thick blade and the spinning rotor.
- Perform further calibration of the physical model predictions against test leakage and force coefficient.
- Begin extensions of the bulk-flow model to include two-component mixtures (liquid in a gas).
- The models will integrate real gas properties, including steam and supercritical CO_2. The analysis will be limited to a centered rotor thus giving force coefficients of the form K_{YY}=K_{XX} and K_{XY}=-K_{YX}

The products of the research will enable TRC members to upgrade their arsenal of predictive tools for ready integration into their engineering design and practice processes.

EFFECT OF SHIMMING ON THE ROTORDYNAMIC FORCE COEFFICIENTS OF A BUMP-TYPE FOIL BEARING (NEW)

Oil-free micro turbomachinery implements bump foil bearings (BFB) for high speed operation (DN>10^6 rpm-mm) with minute drag power losses. While BFBs provide unique advantages, practice shows that rotors supported on BFBs display large amplitude subsynchronous whirl motions, commonly mistaken as rotordynamic instability. In actuality, forced excitations due to mass imbalance cause a hardening stiffness of the bearing underspring structure that produces the nonlinearity. Mechanically preloading BFBs through the addition of metal shims is a simple and inexpensive industrial practice that helps to reduce the amplitude severity and delays the onset of subsynchronous whirl motions. Presently, there are no proven guidelines to select the shim thickness, their number and location in the bearing circumference.

Work is proposed to conduct rotordynamic measurements with a shimmed BFB and to demonstrate its effectiveness in reducing the amplitude of rotor response with enhanced damping. Similar test data with the original bearing will serve as baseline for the comparisons. The specific tasks in 2013-14 are:

a) Install and test the original and shimmed BFB in a dedicated rotordynamic test rig featuring a turbine driven turbocharger.
b) Conduct dynamic load tests with a floating BFB, original and shimmed, to determine the dynamic stiffness and equivalent damping over a range of excitation frequencies (600 Hz max.)
c) For increasing static loads, conduct rotor speed start-up and shut-down tests and record the drag torque and lift-off shaft speed.

The output of the research will quantify the performance of shimmed gas foil bearings with improved rotordynamic performance. The products of the research are important for manufacturers of turbochargers, (cryogenic) turbo expanders, micro gas turbines, and oil-free blowers and compressors.

Tribology Group - Funded Research **2013**

External NEW funds (2012-13) $ 255,817

Principal Investigator(s)	Sponsor Project #	Amount	Project	Dates (GS support)
L. San Andrés 32525/B8820	**Samsung Techwin**	**$ 158,639**	Thrust Collar Analytical Development	09/01/12 – 08/31/14 (1)
L. San Andrés 32525/B8820	**Pratt & Whitney**	**$ 97,178**	Novel SFD for Aircraft Application (Total $436,264 since 2008)	01/01/12 – 08/31/13 (1)

Internal: $196,206 (TRC 2012-13)

Principal Investigator(s)	Sponsor	Amount	Project	Dates (GS support)
L. San Andrés	TRC 32514/1519 X5	**$40,984**	Computational model for tilting pad journal bearings (Year III)	09/01/10 08/31/13
L. San Andrés	TRC 32514/1519 SF	**$28,470**	Linear-Nonlinear force coefficients for squeeze film dampers (Year II)	09/01/11 08/31/13
L. San Andrés	TRC 32514/1519 PD	**$40,984**	Engineered analysis for pocket damper seals and combined labyrinth-brush seals	09/01/12 08/31/13
	TRC 32514/1519 X5	**$41,484**	Automated analysis of time transient responses in nonlinear rotor bearing systems (Year II)	09/01/11 08/31/13
L. San Andrés	TRC 32514/1519 NS	**$44,984**	Making a Wet (foamy) seal and estimating its dynamic forced coefficients	01/01/13 03/31/14

Software licensing through TEES, $60,000 project 32271/84390

Licensee	Amount	Software	Date
KIST	**15,000**	XLGFBTH	Jan-12
FareTrade (Snecma)	**2,000**	Spiralc console	May-12
GERC	**4,000**	Jbfish console	Jun-12
Bosch R	**9,000**	XLGFBpress	Nov-12
GE	**7,500**	Xlhydrojet	Nov-12
GE	**7,500**	XLHydrothrust	Nov-12
AENTL - Korea	**15,000**	XLGFBTH	Feb-13

Research Expenditures Fiscal Year 2012 & 2013: ~ $ 279,697.5+241,133.9

Source: TEES portal May 13, 2013

Tribology Group Publications 2012/2013

	2009	2010	2011	2012	2013	Total 2012-2013
Journal (peer reviewed)	6	11	6	6	0	8
Conference (peer reviewed)	7	7	5	6	5	11
Conference (NOT peer reviewed)	2	2	0		2	2
Book Chapters	1	1				
Accepted/awaiting publication					3	3

below **bold face**=student co-author

2012 Best Paper Award, Structures & Dynamics Committee, ASME IGI (June 2013)
Ryu, K., and San Andrés, L., 2012, ”Effect of Cooling Flow on The Operation of a Hot Rotor-Gas Foil Bearing System,” ASME J. Eng. Gas Turbines Power, vol. **134** (October), 102511 [ASME paper GT2012-68074]

2012 Best Paper Award, Microturbines, Turbochargers, & Small Turbomachines Committee, ASME IGI (June 2013)
San Andrés, L.., Barbarie, V., Bhattacharya, A., and Gjika, K., 2012, “On the Effect of Thermal Energy Transport to the Performance of (Semi) Floating Ring Bearing Systems for Automotive Turbochargers,” ASME J. Eng. Gas Turbines Power, vol. **134** (October), 102507 [ASME paper GT2012-68074]

Journal publications (peer reviewed)

2013

2012 San Andrés, L.., and **Delgado, A**., 2012 “A Novel Bulk-Flow Model for Improved Predictions of Force Coefficients in Grooved Oil Seals Operating Eccentrically,” ASME J. Eng. Gas Turbines Power, vol. 134 (May), 022509 [ASME Paper GT2011-45274]

San Andrés, L., 2012, “Rotordynamic Force Coefficients of Bubbly Mixture Annular Pressure Seals, ”ASME J. Eng. Gas Turbines Power, vol. 134 (Feb), 022503 [ASME Paper GT2011-45264]

Ryu, K., and San Andrés, L., 2012, ”Effect of Cooling Flow on The Operation of a Hot Rotor-Gas Foil Bearing System,” ASME J. Eng. Gas Turbines Power, vol. 134 (October), 102511 [ASME paper GT2012-68074]

San Andrés, L., Barbarie, V., Bhattacharya, A., and Gjika, K., 2012, “On the Effect of Thermal Energy Transport to the Performance of (Semi) Floating Ring Bearing Systems for Automotive Turbochargers,” ASME J. Eng. Gas Turbines Power, vol. 134 (October), 102507 [ASME paper GT2012-68074]

San Andrés, L., 2012, “Damping And Inertia Coefficients for Two Open Ends Squeeze Film Dampers with a Central Groove: Measurements and Predictions,” ASME J. Eng. Gas Turbines Power, vol. 134 (October), 102506, [ASME Paper GT2012-68212].

San Andrés, L., and **Chirathadam, T.,** 2012, “A Metal Mesh Foil Bearing and a Bump-Type Foil Bearing: Comparison of Performance for Two Similar Size Gas Bearings,”ASME J. Eng. Gas Turbines Power, vol. 134 (October), 102501 [ASME paper GT2012-68437].

Peer reviewed Conference publications

2013 ASME Turbo Expo Gas Turbine Conference, San Antonio, TX (June 2013)

J San Andrés, L., and **Seshaghiri, S.,** 2013, “Damping and Inertia Coefficients for Two End Sealed Squeeze Film Dampers with a Central Groove: Measurements and Predictions,” ASME GT2013-94273.

San Andrés, L., and **Ryu, K.,** 2013, “On the Failure of a Gas Foil Bearing: High Temperature Operation without Axial Cooling Flow, ASME GT2013-94244

San Andrés, L., and **Tao, Y.,** 2013, “The Role of Pivot Stiffness on the Dynamics Force Coefficients of Tilting Pad Journal Bearings," ASME GT2013-94403.

J San Andrés, L., and **Chirathadam, T.,** 2013, "Measurements of Rotordynamic Response in a High Temperature Rotor Supported on Two Metal Mesh Foil Bearings," ASME GT2013-94321.

J San Andrés, L., and **Chirathadam, T.,** 2013, "Performance Characteristics of Metal Mesh Foil Bearings: Predictions vs. Measurements," ASME GT2013-945975.

2013 STLE Annual Meeting & Exhibition, May 5-9, Detroit, MI

San Andrés, L., and **Jeung, S.-H,** and **Bradley, G.,** 2013, "Experimental Foirce Coefficients for an Open Ends Squeeze Film Damper Performing Large Amplitude Circular Orbital Motions, Centered and Off-centered."

San Andrés, L., and **Anderson, A.,** 2013, "Leakage for an All-Metal Compliant Seal Operating at High Temperature."

2012 ASME Turbo Expo Gas Turbine Conference, Copenhagen (June 2012)

Jauregui, J.C., DeSantiago, O., and San Andrés, L., 2012, "Identification of Bearing Stiffness and Damping Coefficients Using Phase-Plane Diagrams," ASME Paper GT2012-69980.

J **Ryu, K.,** and San Andrés, L., 2012, "Effect of Cooling Flow on The Operation of a Hot Rotor-Gas Foil Bearing System," ASME paper GT2012-68074

J San Andrés, L., 2012, "Damping And Inertia Coefficients for Two Open Ends Squeeze Film Dampers with a Central Groove: Measurements and Predictions," ASME paper GT2012-68212

J San Andrés, L.., Barbarie, V., Bhatthacharya, A., and Gjika, K., 2012, "On the Effect of Thermal Energy Transport to the Performance of (Semi) Floating Ring Bearing Systems for Automotive Turbochargers," ASME paper GT2012-68074

J San Andrés, L., and **Chirathadam, T.,** 2012, "A Metal Mesh Foil Bearing and a Bump-Type Foil Bearing: Comparison of Performance for Two Similar Size Gas Bearings," ASME paper GT2012-68437

ASME International Mechanical Engineering Congress & Exhibition, Nov. 9-15, Houston, TX

San Andrés, L., 2012, "Extended Finite Element Analysis of Journal Bearing Forced Performance to include Fluid Inertia Force Coefficients," IMECE2012-87713.

PUBLICATIONS OF BOOKS OR AUTHORITATIVE REFERENCES

Accepted for journal & in print (*) 2013

ASME J Eng Gas Turbines and Power

San Andrés, L., and **Seshaghiri, S.,** 2013, "Damping and Inertia Coefficients for Two End Sealed Squeeze Film Dampers with a Central Groove: Measurements and Preditions," ASME GT2013-94273.

San Andrés, L., and **Chirathadam, T.,** 2013, "Measurements of Rotordynamic Response in a High Temperature Rotor Supported on Two Metal Mesh Foil Bearings," ASME GT2013-94321.

San Andrés, L., and **Chirathadam, T.,** 2013, "Performance Characteristics of Metal Mesh Foil Bearings: Predictions vs. Measurements," ASME GT2013-945975.

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