TRC CONTINUATION PROPOSAL 2015- 2016

Rotordynamics Software with Nonlinear Magnetic Bearings, Flexible Rotor, Flexible Foundation and High Fidelity Catcher Bearing

by Dr. Alan Palazzolo a-palazzolo@tamu.edu, Xiao Kang

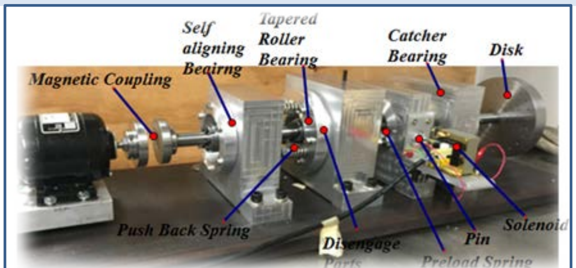
Objectives

The standard rotordynamic code for magnetic bearing systems cannot meet the industrial requirements since it does linear analysis without saturation features, no bandwidth limitations, no electric noise input, and no modeling of magnetic bearing actuator. The objectives of the TRC magnetic bearing code include:

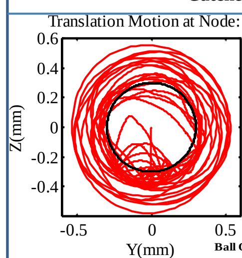
- Develop user friendly simulation software for rotordynamic systems with nonlinear magnetic bearings, flexible rotor, and flexible support, and integrate this into $XLTRC^2$.
- Improve the reliability of the predictions of stability and response by including nonlinear properties for saturation, 3D thermal "hot spot", 3D flux field, power loss, and check the designed system with ISO standards.
- Automatic system optimization design with genetic algorithms, to guide users on the parameters selection.

Accomplishments for 2015 – 2016

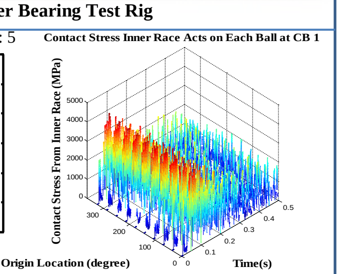
- **Catcher Bearing test rig development and experimentation; All the parts have been finished.**
- **Complex model reduction of the rotor and AMB model to increase the calculation speed;**
- **High fidelity nonlinear catcher bearing model with life prediction considers the dynamic and thermal behavior of inner race, outer race and each bearing ball;**
- **FEM code for rotor dropping on to the Catcher Bearing with the Squeeze film damper (include SFD groove);**
- **FEM code for rotor dropping on to the Catcher bearing with the wave spring (corrugated ribbon) considering spring's tangential sliding and column friction force;**
- **The non-collocated AMB functionality in XLTRC2;**
- **User interface improvement**



Catcher Bearing Test Rig



Rotor orbit



Contact stress on each bearing ball

Current Functionalities:

1. Linear Rotordynamic Code

- ❖ Rigid Support Model
- ➢ Modal analysis
- ▪ Stability, eigenvalues analysis, mode shapes
- ➢ Root locus
- ➢ Imbalance response
- ➢ Run-out response
- ➢ PD controller optimization
- ➢ Power loss analysis
- ➢ Transient analysis
- ➢ System optimization with genetic algorithms
- ➢ ISO standard check
- ❖ Flexible Support Model
- ▪ All above analysis with flexible support

3. Thermal Analysis Code

- ➢ Power loss and 2D FEM thermal analysis

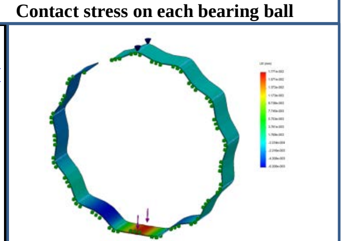
2. Nonlinear Rotordynamic Code

Nonlinearities: Power amplifier saturation, nonlinear B-H curve, and catcher bearing effects

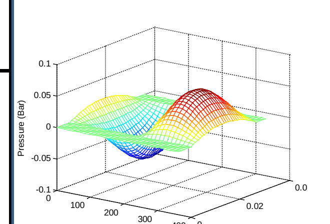
- ➢ Transient analysis
- ➢ Ball Bearing Coefficient Calculation
- ➢ Catcher bearing drop events with life prediction
- ▪ Nonlinear High fidelity catcher bearings with drop events simulation, thermal modeling, catcher bearing life prediction, and catcher bearing dampers effects (SFD, O-ring, Wavy Spring)
- ➢ System optimization with genetic algorithms

4. User Manual

- ➢ Software installation instructions
- ➢ Model setup procedure description
- ➢ Ansys/Maxwell 3D flux field analysis instructions
- ➢ Optimization algorithms for magnetic bearing design



Wavy Spring



SFD Pressure Distribution

Proposed Work for 2016 – 2017

❖ **Code Integration into XLTRC[2]**

1) High fidelity modeling of catcher bearing drop events with life prediction;

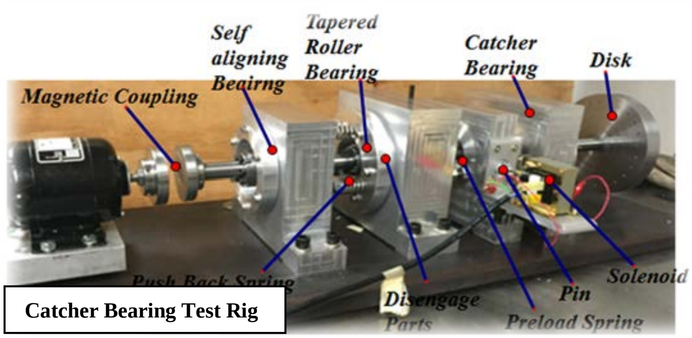
❖ **Expanded Functionalities**

2) Catcher Bearings
- Simulation models including 3D solid-self lubricated sleeve CB, 2D temperature distribution around Catcher Bearing inner race and outer race.
- Drop test experiments and correlation with prediction.
- Catcher Bearing Test Rig Improvements. Add temperature and load sensor.
- Upgrade to test larger catcher bearings with heavier loads and higher speeds;
- Drop test with different catcher bearing clearances, dampers, rotational speeds and side loads.
- Fatigue life calculation of wavy spring.
- Higher fidelity squeeze film dampers designed for large motion impact loading.

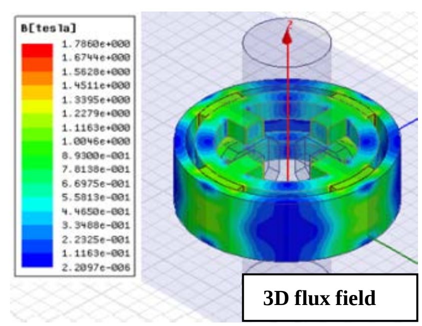
3) Control Law Development
- System identification of plant;
- Controller development based on the identified system.

4) MB Actuator Design
- 3D Magnetics and Thermal solvers to replace commercial solvers;
- Optimization of isolated MB actuator.

5) Automatic API 618 Check for Magnetic Bearing system;



Catcher Bearing Test Rig


3D flux field

❖ **User Interface & Code Optimization/Compiling**

6) English/SI units;
7) Quicker execution for optimization features for rotordynamic system simulation by adding adaptive numerical integrator;
8) Improve user friendliness of the code by adding run time diagnostics capability.

❖ **Customization and Improvement based on users feedback and requests** (New features added this for GE and Praxair)

Budget

1 PhD Student, 12 months $2,200/mo. Salary, $197/mo. Insurance, 2.5% Fringe on salary, approx. $9000 Tuition and Fees, $ 4,000 on Test rig improvements (force, temperature sensor & test rig m odification). ***Total: $42,424***