



U.S. Department of Energy
**Energy Efficiency
and Renewable Energy**



Low-Friction Coatings and Materials for Fuel Cell Air Compressors

O. O. Ajayi, A. Erdemir, and G. R. Fenske

**2004 DOE HFCIT Program Review
Presentation**

April 23, 2004

**This presentation does not contain any
proprietary or confidential information.**

Argonne National Laboratory



A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago



Objectives

Technology Issue and Relevance:

Fuel cell stacks requires a compact ,lightweight, highly efficient, and low-cost compressor/expander. No off-the-shelf compressor technology that can meet DOE target exists. Several contractors are developing compressor/expander systems for DOE. Efficiency, reliability and durability of such system are dependent on effective lubrication of critical components such as bearings and seals. Such components cannot be oil lubricated - oil will contaminate fuel cell stacks.

Objectives: Develop and evaluate low-friction and wear-resistant coatings and/or materials for critical components of air compressor/expanders being developed for fuel cells by DOE contractors.

Budget & Effort: 200K FY04; 2 staff + visiting scientist & student

Technical Barriers and Targets

- **Transportation Systems Barriers**
 - A. Compressors/Expanders

- **DOE Technical Targets for 50-kW System Compressor for 2010**
 - Cost - \$6/kW
 - Efficiency at Full Flow - 80%
 - Volume - 8-11 L
 - Weight - 8-11 Kg
 - Turndown Ratio – 10-15
 - Noise dB(A) at 2 meters – 70 dB(A)

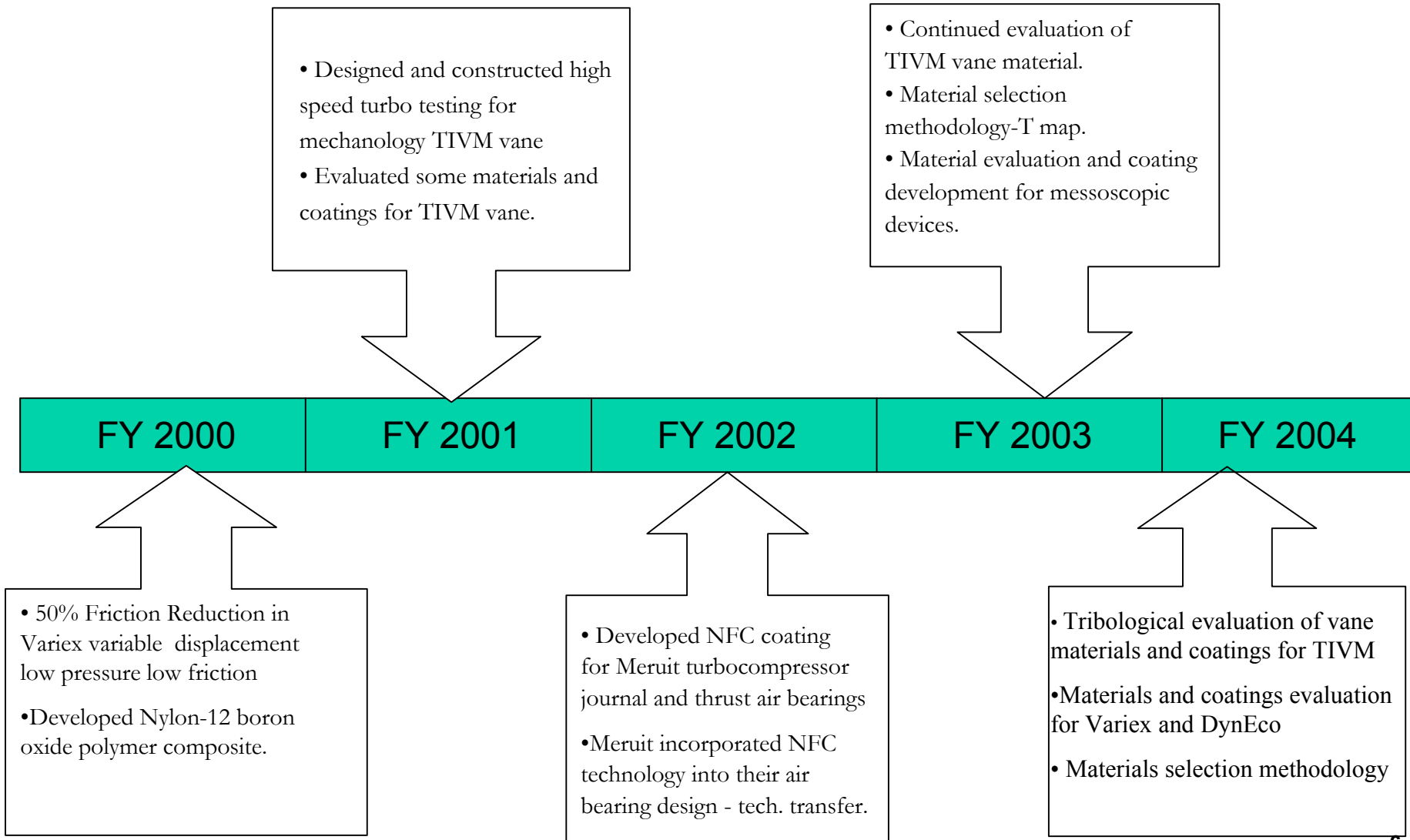
Approach

- Work with various DOE contractors to
 - Identify tribologically challenging critical compressor components
 - Apply and evaluate Argonne’s near-frictionless carbon coatings to the components when appropriate
 - Develop and evaluate polymer composite materials with boric acid solid lubricant.
 - Identify and evaluate other candidate materials for various specific compressor components
 - Transfer developed technology to DOE contractors
- Develop a tribology-based material selection methodology applicable to all the DOE compressor contractor’s operating conditions and requirements

Project Safety

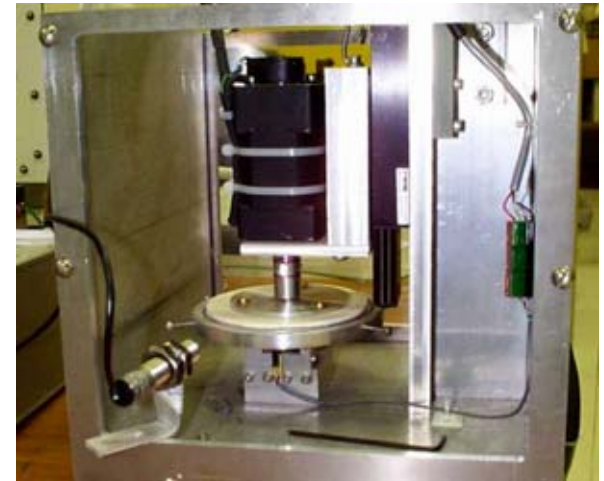
- **All the tasks in the project are on the laboratory bench top scale.**
- **It is the policy of Argonne National Laboratory that its activities be conducted in such a manner that worker safety, public safety, and protection of the environment are given highest priority**
- **An environmental evaluation has been completed in accordance with the DOE-approved ANL-E process for implementation of the National Environmental Policy Act.**

Project Timeline



Mechanology TIVM Vane Materials Evaluation

- **To meet DOE efficiency target, Mechanology's TIVM compressor vanes require sliding friction coefficient < 0.15 under high sliding contact.**
 - Low-cost material – to meet cost target
 - Stable friction behavior – low noise
 - Wear resistant – for durability target
- **Evaluated two classes of engineering polymers – PEEK and Ultem, and NFC coating**
 - Three types of ball material – 440C stainless steel, Aluminum alloy (2017) and NFC coated steel ball.
- **Test conducted under room and 100% relative humidity**



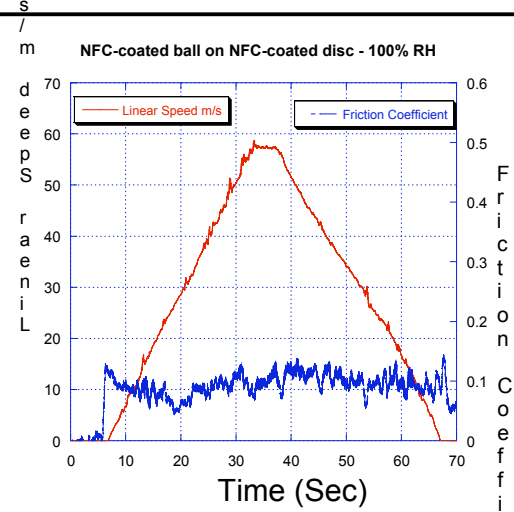
High-speed three-ball-on disc test rig

Disc Materials

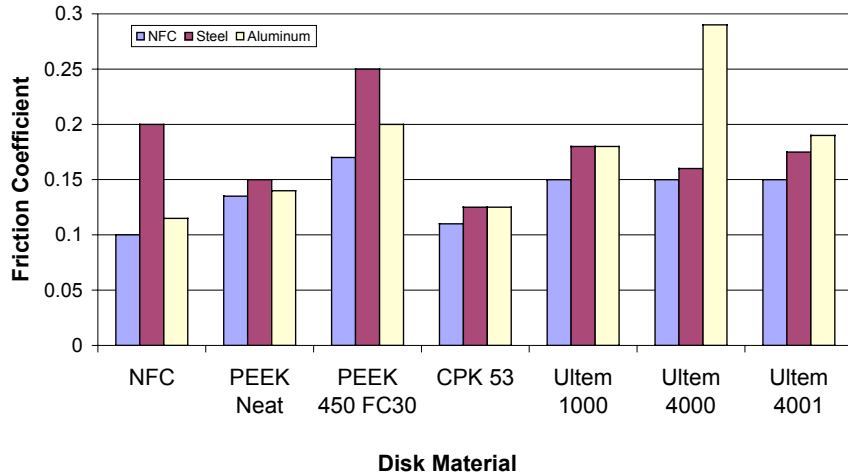
<u>Material</u>	<u>Description</u>
PEEK FC30	Polyetheretherketone with 30% carbon fiber/powder
PEEK CPK 53	Weaved Carbon Fiber Reinforced PEEK
Ultem 1000	Polyetherimide base resin
Ultem 4000	Polyetherimide with glass reinforced and lubricant
Ultem 4001	Polyetherimide with lubricant additive
NFC Coated Steel	ANL's Amorphous Carbon Coating
Nylatron	Nylon & Molybdenum Disulphide (MoS ₂)
Ertalyte TX	Polyethylene Terephthalate (PET-P) w/solid lubricant
Fluorosint 500	Polytetrafluoroethylene (PTFE)

Friction Behavior

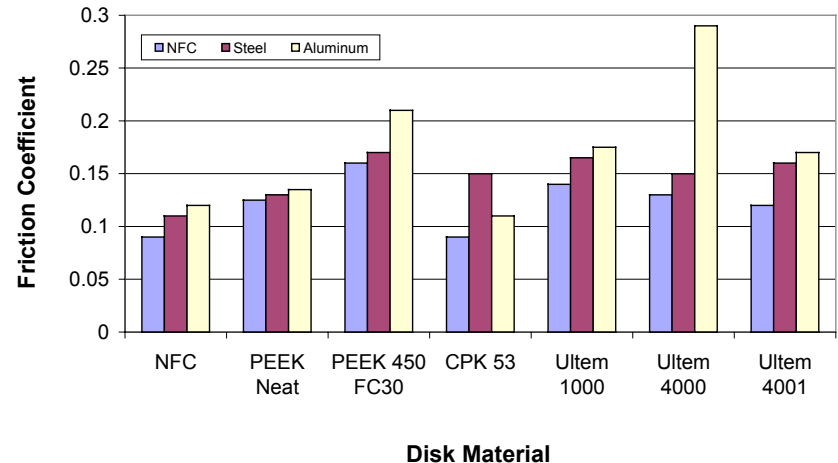
- Some candidate material and coatings will meet the < 0.15 friction coefficient requirement under both dry and humid environments



Average Friction Coefficient at Ambient Room Humidity (30%-40%RH)



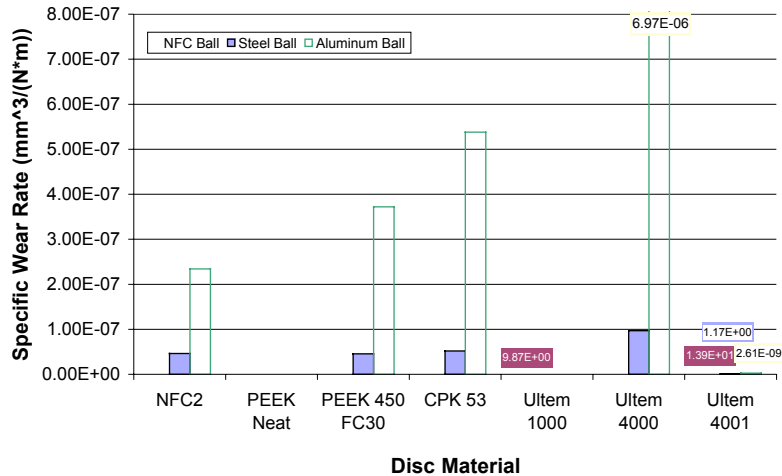
Average Friction Coefficient in 100% RH



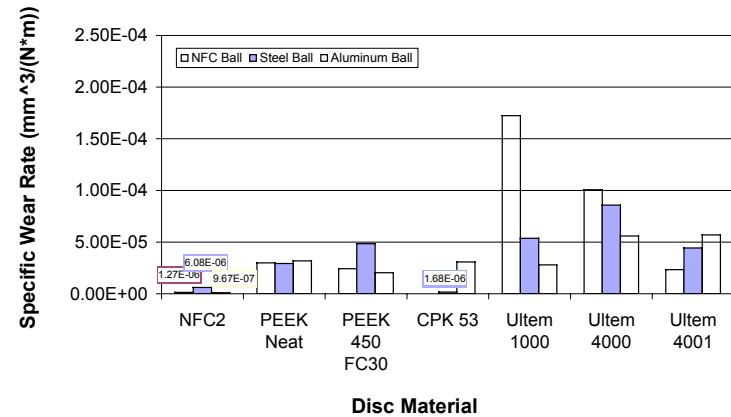
Wear Behavior

- Wear rate in some of the candidate materials and coating are acceptable in both dry and humid environments

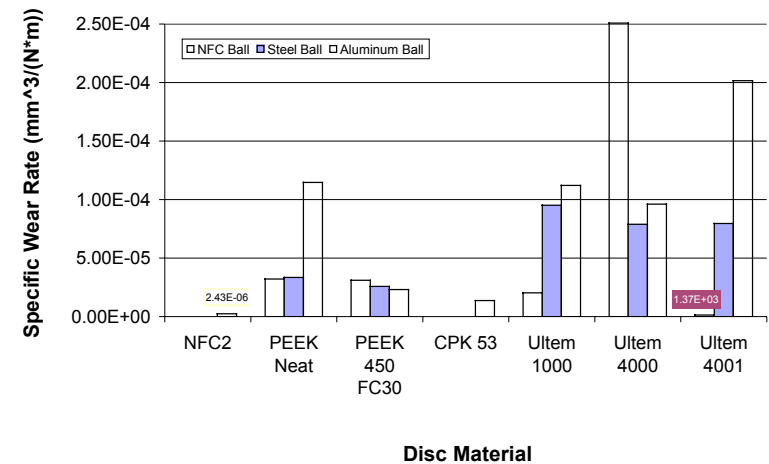
Specific Wear Rate for Ball Wear in Ambient RH



Specific Wear Rate for Disc Wear in Ambient RH

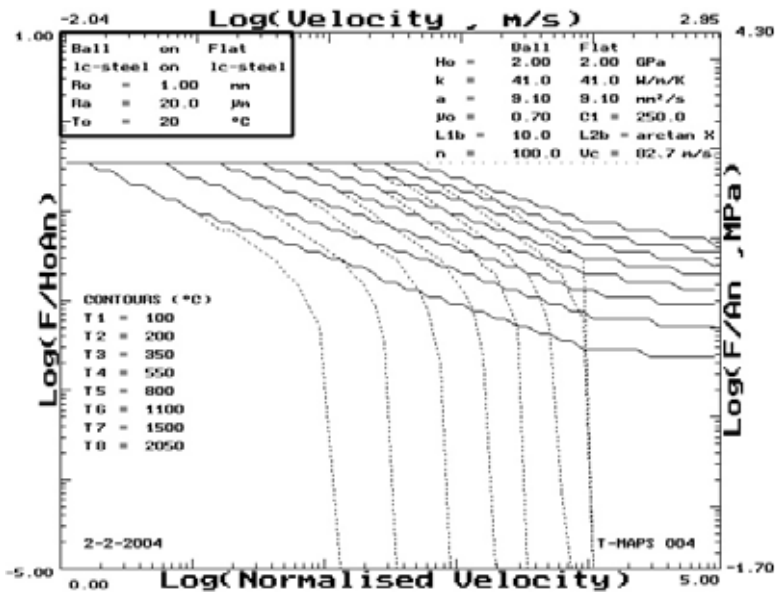


Specific Wear Rate for Disc Wear in 100% RH

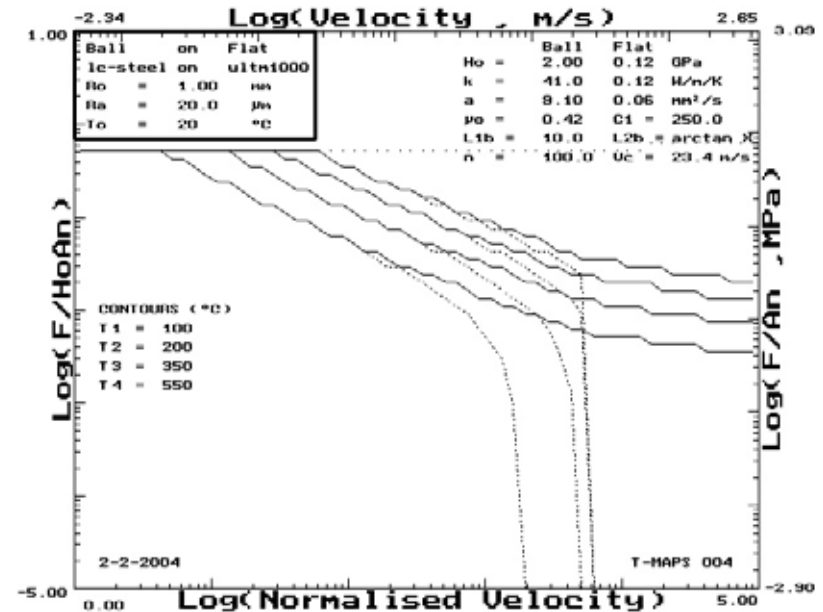


Friction Heat Calculations

- As expected, significant differences in frictional heating characteristics of steel-on-steel contact and steel-on-polymer contact pairs
 - Effect of differences in thermal conductivity



T-map for Steel-on-steel contact



T-map for Steel-on-Ultem 1000 polymer contact

Interactions and Collaborations

- **Meruit Inc. and Texas AM: Coated several components for turbocompressor testing at Texas AM (Prof. San Andres).**
- **Mesoscopic Devices: Coated components for blowers for small fuel cells for testing.**
- **Mechanology LLC: Evaluation and characterization of tribological behavior of candidate materials for TIVM.**
- **Variex Corp: Material tribological evaluation for vane compressor.**
- **DynEco: Material/coating evaluation for vane compressor**

O. O. Ajayi, J. B. Woodford, A. Erdemir, and G. R. Fenske, “Performance of Amorphous Carbon Coatings in Turbocompressor Air Bearing” SAE Technical paper 2002-01-1922, Presented at 2002 Future Car Congress.

Responses to Previous Year Reviewers' comments

- **Work on real devices**
 - Components were coated for real turbocompressor device for testing by Meruit Inc.
 - Prototype components were coated for Mesoscopic Devices Inc. for real device testing
- **Focus on specific friction problems for compressor/blower**
 - Working with Mechanology LLC to address specific friction and wear needs in TIVM

Future Work

- **Continue work with DOE compressor developers to address critical tribological and material issues**
 - Mechanology TIVM
 - *Comprehensive tribological performance characterization of candidate materials and coating*
 - *Coat prototype components for device testing by mechanology*
 - Variex Vane compressors
 - *Evaluate materials and coatings under prototypical operating conditions.*
 - DynEco Vane compressors
 - *Evaluate tribological and corrosion properties under*
- **Continue development of compressor/expander material selection methodology.**
- **Expand current effort to include compressor/expander units for direct hydrogen systems**