CONTENTS OF DISCUSSION

• Introduction
  ➢ Description of Dynamic Thermal Barriers
  ➢ Types/Construction of Dynamic Thermal Barriers

• Objectives and Approach
  ➢ Project objectives
  ➢ Tribometer upgrades and checkout
  ➢ Test materials & test parameters

• Triobological Results
  ➢ Previous results from NASP
  ➢ Tribopairs (base materials and coatings)
  ➢ Temperature
  ➢ Load

• Summary, Conclusions, and Challenges
AN INTEGRAL PART OF THE TPS

- Referred to as “dynamic thermal seals” or “dynamic seals”
- High-temp. ceramic-based materials
- Installed in TPS interface gaps between moving structures
- Roles
  - Thermal – limit inboard temperatures
  - Structural/physical – survive temps. and wear, not impede actuation/operation of control surface, accommodate deflections
DYNAMIC THERMAL SEALS

- Compliant Thermal Barriers (CTB)
  - Nextel™ sheath
  - Saffil® core, spring tube
  - Higher temps, lower stiffness, higher leakage

- Rope Thermal Barriers (RTB)
  - Nextel™ sheath
  - Fiber/fabric/rope core
  - Higher temps, higher stiffness, lower leakage

- Hybrid Sheath Thermal Barriers (HSTB)
  - Metallic wire braid/Nextel™ sheath
  - Saffil®, fiber/fabric/rope core
  - Better wear resistance, lower temps

- Wafer Seals
  - Monolithic materials (metals, ceramics, etc.)
  - Low leakage (tight tolerances)
  - Require preloader
OBJECTIVES

• Overall Objectives
  ➢ Develop a repeatable screening tool to assess tribological performance of dynamic thermal barrier materials
  ➢ Create a database of thermal barrier tribological performance (against TPS or propulsion materials)
  ➢ Improve tribological performance of dynamic thermal barriers

• Dynamic thermal barrier triobological performance
  ➢ Baseline performance against several materials
    o Metal
    o Non-ablative TPS
    o Ablative TPS
  ➢ Effects of various parameters
    o Load
    o Temperature
    o Coatings
## High Temperature Tribometer Checkout Results

<table>
<thead>
<tr>
<th>Test ID</th>
<th>Date</th>
<th>Pin</th>
<th>Plate</th>
<th>Normal Load</th>
<th>Est. CoF, sliding</th>
<th>Published Data</th>
<th>Source</th>
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<td>304 SS</td>
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</table>
# High Temperature Wear-Resistant Coating Candidates

## Introduction

**Objective**

- Challenges with coatings — chemical compatibility/reactions, coating thickness, adherence
- Investigated a nanocomposite MAX phase type coating (SwRI Surface Engineering)

## Approach

<table>
<thead>
<tr>
<th>Coating</th>
<th>Room Temp CoF</th>
<th>High Temp CoF</th>
<th>Max Tested Temp (°C/°F)</th>
<th>Predicted Max Thermal Stability (°C/°F)</th>
<th>Trade Study Weight</th>
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</thead>
<tbody>
<tr>
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<td>0.27</td>
<td>1000/1832</td>
<td>1123/2053</td>
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<td>Silver Tantalate (AgTaO₃)</td>
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<td>750/1382</td>
<td>1172/2142</td>
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<td>800/1472</td>
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<td>0.34</td>
<td>1000/1832</td>
<td>1000/1832</td>
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<td>MAX phase Ti₂AlC</td>
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<td>0.36</td>
<td>550/1022</td>
<td>1400/2552</td>
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<td>MAX phase Ti₃SiC₂</td>
<td>0.60</td>
<td>0.62</td>
<td>550/1022</td>
<td>1400/2552</td>
<td>249</td>
</tr>
</tbody>
</table>

| xo  | 0.5 | 0.5 | 1100 | 1200 |
| w   | 5   | 9   | 7    | 10   |
Test Approach

- Test Samples
  - Seal material: Nextel 312 (AF-20) and Nextel 440 (BF-20)
    - 5 harness satin weave
    - Warp: 30 threads per in.; Fill: 26 threads per inch
  - Fabric Coatings: None, TaSiN, TaSiCN (nano-composite coatings)
  - Wear surface: 4130 steel, AETB-8 tile, IN-625
- Test Parameters
  - Load: 2, 8 psi (14, 55 kPa)
  - Temperature: Ambient, 1500°F (Ambient, 815°C)
  - At least 3 tests were conducted for each tribopair at a given test condition
**WEAR RESULTS: PREVIOUS TESTING**


**Approach**
- Conducted numerous studies
- Pin-on-disk geometry (non-reciprocating)
- “Pin” materials: Nextel 312, Nextel 440, Nextel 550, Nextel 610
- Disk materials: IN 718, IN X-750, Ti₃AlNb
- Temperatures: Ambient - 1832°F (Ambient – 1000°C)
- Loads: 23 - 382 psi (160 - 2633 kPa)
- Coatings: Ag, CaF2, BN, Au

**Results**
- CTF generally decreased with increasing temperature (oxide-based fibers)
- CoF’s: ~0.6 - 1.0
WEAR RESULTS: EFFECT OF PRELOAD AND CYCLE NUMBER

- CoF lower at higher preload, though likely not statistically significant
- At RT against 4130 steel, low initial CoF, than it increases
- At RT against IN-625, low initial CoF, than it increases
- At 1500°F, CoF was significantly higher starting off and then decreased to fairly high value
**Wear Results: Type of Nextel**

- **Nextel 440 showed slight improvement over Nextel 312**
  - Most evident against Shuttle tile
  - Higher CTF likely due to higher breaking strength of N440 (250 lb/in. vs. 150 lbf/in.)
- **Shuttle tile exhibited lower CoF than 4130 steel**
- **CoF appeared to significantly increase for higher temperatures with these tribomaterials**
WEAR RESULTS: TYPE OF NEXTEL

<table>
<thead>
<tr>
<th>Type of Nextel</th>
<th>RT</th>
<th>1500°F</th>
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</thead>
<tbody>
<tr>
<td>Nextel 312</td>
<td>4130 Steel</td>
<td>Shuttle Tile</td>
</tr>
<tr>
<td>Nextel 440</td>
<td>4130 Steel</td>
<td>Shuttle Tile</td>
</tr>
</tbody>
</table>

- **Introduction**
- **Objective**
- **Approach**
- **Results**
- **Summary**
**Wear Results: Pin Material**

- Shuttle tile showed some difference when compared to metals
  - Slightly lower CTF
  - Most evident against Shuttle tile
- Shuttle tile exhibited lower CoF than 4130 steel
- CoF appeared to increase significantly with higher temperatures with these tribomaterials
Wear Results: Pin Material

- **4130 Steel**
- **IN 625**
- **Shuttle Tile**

**RT**

**1500°F**
WEAR RESULTS: EFFECT OF COATINGS

- No significant improvement in CTF with coatings
- Performance comparable (possibly slightly worse) than uncoated Nextel 312
- Possible coating adhesion issues and reactions with Nextel
WEAR RESULTS: EFFECT OF COATINGS

N312

RT

1500°F

N312 + NTA-3

N312 + NTA-4
WEAR RESULTS: EFFECT OF COATINGS

N312

RT

N312 + NTA-5

1500°F

N312 + NTA-6
SUMMARY, CONCLUSIONS, & CHALLENGES

• Rig Upgrade
  ➢ Improved instrumentation, modernized DAQ, augmented stroke length
  ➢ Produced believable, reliable, repeatable results
  ➢ Learned significant lessons to help in design of a newer higher-temperature rig

• Wear Performance of Nextel
  ➢ Nextel durability insufficient for high temperature thermal barrier dynamic operation
    • Significant degradation in wear performance at high temperatures 1500°F
    • Require wear-resistant coatings
  ➢ Initial tests of Nextel against TPS materials demonstrated poor wear resistance, even at room temperature
  ➢ Preliminary tests with Ta-based nano-composite coatings showed no improvement

• Challenges
  ➢ Coatings that are adherent, “non-reactive,” protective, low CoF
  ➢ Coatings appear to work “better” when deposited on opposing wear surface
    • Most studies have deposited on metallic or ceramic substrates
    • Minimal evidence for success depositing on thermal barrier fabric materials
REFERENCES


