Selbstschmierende Metallmatrixcomposite aus der Weltraumforschung für Kugellager in der Luftfahrt

(Self-lubricating Composites)

General manager: Dr N. Gamsjaeger
Head of testhouse: Dr. A. Merstallinger

andreas.merstallinger@aac-research.at
History of AAC

Spin-Off

- **Reorganisation of AIT in 2010**: Spin-Off of the business field „Aerospace and Advanced Composites“ into a SME
- **Objective**: Keep **Competence in Aeronautic and Space** in Austria

<table>
<thead>
<tr>
<th>Mobility</th>
<th>Energy</th>
<th>Health</th>
<th>Security</th>
<th>Policy</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIT Austrian Institute of Technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- LKR

<table>
<thead>
<tr>
<th>AAC</th>
<th>PTC</th>
<th>PIM</th>
<th>SPA</th>
<th>ADG</th>
</tr>
</thead>
<tbody>
<tr>
<td>SME (Shareholder also AC2T)</td>
<td>SME</td>
<td>Pim-Tech, SME</td>
<td>Dept. of Applied Uni Wr Neustadt</td>
<td>Montan Uni Leoben</td>
</tr>
</tbody>
</table>
Company data

- Founded August 2010
- Headquarters: Wiener Neustadt, Viktor-Kaplan-Straße 2 (business location „Technology Park Seibersdorf“ until June 2012, then TFZ Wiener Neustadt)
- Shareholders: Staff members, AC²T research GmbH
- 19 scientific und technical staff members

Mission statement

AAC is positioning itself as the only commercial provider of research, development and testing in the field of composite materials for aerospace and terrestrial applications in Austria.
DIVISIONS & THEIR SERVICES

Polymer Composites
- Development of coatings, adhesives and surface modifications
- Nano composites
- Process modeling and verification of resin infusions
- Structural Health Monitoring

Inorganic Composites
- Development of ceramic nano particles
- Functional inorganic composites and coatings
- High temperature ceramics

Materials & Components Testhouse
- Microstructure – Material analysis and support
- Materials & Components tests under extreme environments
- Virtuel testing

Global services in the value-added chain of customer:
Research – Development – Prototypes
Objectives of the Testhouse

Assistance to ESTEC by characterisation and qualification of materials and processes of industrial suppliers

- Cooperation since 1989 by frame contract
- Cooperation partner at ESTEC: QM materials & processes division
Objectives of CuMMC-Development for space applications

- **Material Development**
  - Metal Matrix Composites (CuMMC) with
  - Embedded dry Lubricants (MoS$_2$)
- **For Environments of**
  - Vacuum, inert gases, air (humid)
  - High Temperatures of up to 300°C
- **For high temperature Tribo-Applications**
  - Bushes or cages for bearings
  - Slip-rings (electrical)
- **Advantages**
  - Dry lubrication embedded in a metal
  - Usage temperature (> 300°C)
  - Unique products made in Europe!
### Environment – Restraints - Products

<table>
<thead>
<tr>
<th>Environment</th>
<th>Solid lubricant</th>
<th>Matrix</th>
<th>Manufacturing restraints</th>
<th>Available products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground (RT,air)</td>
<td>Grafit, PTFE</td>
<td>Polymer, Metal</td>
<td></td>
<td>“Many” “Many”</td>
</tr>
<tr>
<td>Vacuum (RT)</td>
<td>MoS$_2$, PTFE, Lead only Bronze, PTFE</td>
<td>Polymer, Metal, Metal, Polymer with fibres</td>
<td>MoS$_2$ reacts</td>
<td>“Many” Few Few</td>
</tr>
<tr>
<td>Vacuum (HT)</td>
<td>MoS$_2$, MoS$_2$</td>
<td>Polyimides (max 300° C), Metal</td>
<td></td>
<td>Tecasint None !</td>
</tr>
</tbody>
</table>

### Advantage of metal-to-polymer composite at vacuum & high temperature:

- Higher Stiffness (up to high temperatures)
- Radiation resistance
- Thermal expansion close to steel (bearings)
- Good electrical & thermal conductance

### Disadvantage

- No products
Conventional materials show limitations ...

<table>
<thead>
<tr>
<th>Targets for space (elevated temperatures)</th>
<th>Conventional MMC offer</th>
<th>Conventional PolyMC offer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid lubrication (no liquids)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Lubrication by MoS$_2$ or similar</td>
<td>No (grafite!)</td>
<td>Yes</td>
</tr>
<tr>
<td>High stiffness for small bearings</td>
<td>Yes</td>
<td>Lower</td>
</tr>
<tr>
<td>Good machinability</td>
<td>No</td>
<td>Partly</td>
</tr>
<tr>
<td>Not degradable by Radiation</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>High temperature (mechanical)</td>
<td>Partly</td>
<td>Partly (Polyimides)</td>
</tr>
<tr>
<td>No volatile (outgassing or sublimation)</td>
<td>Partly (sublimation)</td>
<td>Partly</td>
</tr>
</tbody>
</table>

CuMMC (by AAC) offers all these targets

- MoS$_2$ can now be combined with bronze ...
Processing – Selection of composition

Selection of composites and processes:

Process based on powder metallurgy

- Powder pre-treatment (“CP”)
- Hot compaction *

<table>
<thead>
<tr>
<th>Designation</th>
<th>Type</th>
<th>Composition Fillers in v%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu12Sn-5M</td>
<td>Cp</td>
<td>5 v% MoS₂</td>
</tr>
<tr>
<td>Cu12Sn-25M</td>
<td>Cp</td>
<td>25 v% MoS₂</td>
</tr>
<tr>
<td>Cu12Sn-40M</td>
<td>Cp</td>
<td>40 v% MoS₂</td>
</tr>
<tr>
<td>Cu12Sn-12M15CfP</td>
<td>Cp</td>
<td>12 v% MoS₂, 15 v% Carbon fibres</td>
</tr>
<tr>
<td>Cu12Sn-25M15CfP</td>
<td>Cp</td>
<td>25 v% MoS₂, 15 v% Carbon fibres</td>
</tr>
<tr>
<td>Cu12Sn-35M15CfP</td>
<td>Cp</td>
<td>35 v% MoS₂, 15 v% Carbon fibres</td>
</tr>
</tbody>
</table>

* Hot compaction process in cooperation with
Ball bearing with CuMMC cage

Bearing tests

- Ball bearings angular contact type
- Races: Cronidur, partly MoS$_2$ coated, with Balls Si$_3$N$_4$
- Testing at 100rpm up to 250,000 revolutions, at RT and 300°C

Results – post examinations after 300°C

- Races and balls in good condition with lubricant transfer
- No significant wear in cage (5-10µm depth)
- No dimensional changes of cage !!
Ball bearing with CuMMC cage

Comparison to references at high temperatures

- References data from published plots (no values available) for up to 250,000 revs
- Temperature: CuMMC at 300°C, references only at 250°C !!

- Torque comparable to competitors
- Advantage: CuMMC as full cage possible due to low CTE (polymer inserts in Ti-frame)

![Graph showing torque comparison]

Running-In Steady
Results – re-assembled bearing after 1 year storage in air

- Typically: solid lubricant materials degrade when running and stored in air
- CuMMC cage only (no additional coatings)

➤ Despite of storage in humid air, torque afterwards is similar to testing in „new stage“
Conclusion

- A New self lubricating material is available
  - Metal based composite (CuMMC made in europe)
  - Main data necessary for space applications is available (tribo, mechanical, CTE, dimensional stability, machinability)

- Ball Bearing tests (CuMMC as cage)
  - Cages dimensionally stable, almost no wear
  - Good performance at 300°C with add. coatings (competitor materials up to max 250°C)

- Journal bearing tests (CuMMC as bush)
  - Bushes no measurable wear
  - Low torque (comparable to PoD)

- Slip-Rings (CuMMC as disc)
  - Reasonable low resistance and noise at 2,5A and 300°C
Advantages

- Dry lubrication embedded in a „metal“
- Vacuum, inert gases, air (humid)
- High Temperatures of up to 300°C (optional to 450°C)
- Bushes or cages for bearings
- Thermal expansion similar to steel
- No creep (compared to polymers)

Possible applications

- Ball bearings for aircraft (high temperatures, dry), e.g. air bleed systems
- Joints and gaskets for high pressure compressors or high temperature vacuum equipment
Thank you!

Andreas Merstallinger et al
andreas.merstallinger@aac-research.at

Acknowledgement

Part of presented results was funded by European Space Agency (ESA)