Transferring the Experience and Technology of Electric Mobility into Aircraft

04 February 2015
Toulouse

Peter Glöckner
Schaeffler Group – BU Aerospace
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schaeffler Group</td>
</tr>
<tr>
<td>2</td>
<td>Motivation</td>
</tr>
<tr>
<td>3</td>
<td>High Efficient State of the Art Rolling Element Bearing Systems</td>
</tr>
<tr>
<td>4</td>
<td>High Efficient State of the Art e-Mobility Systems and potential MEA Transfer</td>
</tr>
<tr>
<td>5</td>
<td>Summary</td>
</tr>
</tbody>
</table>
# Transferring the Experience and Technology of Electric Mobility into Aircraft

<table>
<thead>
<tr>
<th>1</th>
<th>Schaeffler Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Motivation</td>
</tr>
<tr>
<td>3</td>
<td>High Efficient State of the Art Rolling Element Bearing Systems</td>
</tr>
<tr>
<td>4</td>
<td>High Efficient State of the Art e-Mobility Systems and potential MEA Transfer</td>
</tr>
<tr>
<td>5</td>
<td>Summary</td>
</tr>
</tbody>
</table>
“Together we move the world”
### Schaeffler Group

<table>
<thead>
<tr>
<th>Employees worldwide: More than 80,000</th>
<th>Sales (FY 2013) worldwide: € 11.2 billion</th>
<th>168 locations in 49 countries</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales in million euros</th>
<th>Proportion in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>7,336</td>
<td>Europe 56</td>
</tr>
<tr>
<td>2010</td>
<td>9,495</td>
<td>Asia/Pacific 23</td>
</tr>
<tr>
<td>2011</td>
<td>10,694</td>
<td>South America 5</td>
</tr>
<tr>
<td>2012</td>
<td>11,125</td>
<td>North America 16</td>
</tr>
<tr>
<td>2013</td>
<td>11,205</td>
<td></td>
</tr>
</tbody>
</table>

*Structure in effect until December 31, 2013*
<table>
<thead>
<tr>
<th>Sector</th>
<th>Tapered roller bearings</th>
<th>Ball bearings</th>
<th>Needle roller bearings</th>
<th>Spherical roller bearings</th>
<th>Cylindrical roller bearings</th>
<th>Linear technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Transmission</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerospace</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Industries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renewable Energies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid and Pneumatics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer Products / Medical Systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Railway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motorcycles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-Highway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production Machinery</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Schaeffler Group – Industrial Division

The information in this document is the property of FAG Aerospace GmbH & Co. KG and may not be copied or communicated to a third party for any purpose other than that for which it is supplied without express written authority of FAG Aerospace GmbH & Co. KG.
Special Bearing Systems for Aerospace Applications

Main shaft and gearbox bearing supports, e.g. for the Boeing 787 Dreamliner and Airbus A 380

Gearbox, swash plate, and transmission shaft bearings for helicopters

Special bearings for rocket engines, e.g. turbo pump bearings (Space Shuttle) and cross pin bearings (Ariane 5)

High-precision bearings in the joints of the robotic arm of the Phoenix Mars lander
# Transferring the Experience and Technology of Electric Mobility into Aircraft

1. Schaeffler Group

2. Motivation

3. High Efficient State of the Art Rolling Element Bearing Systems

4. High Efficient State of the Art e-Mobility Systems and potential MEA Transfer

5. Summary
Motivation

Motivation: Reduction in Fuel Burn, Emissions & Noise

Fuel Burn - Level 2000

Todays Modern Aero Engines

Advanced Aircraft Configurations

Geared Fan

Recuperating Aero Engines (with heat exchanger)

2030 Technologies

20-35% New Engines

Open Rotor

20% New Aircraft Config's

Air Traffic Management (ATM)

10% ATM

Minimum 50% Reduction in Fuel Burn and Emissions
# Transferring the Experience and Technology of Electric Mobility into Aircraft

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td>Schaeffler Group</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Motivation</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>High Efficient State of the Art Rolling Element Bearing Systems</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>High Efficient State of the Art e-Mobility Systems and potential MEA Transfer</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Summary</td>
</tr>
</tbody>
</table>
High Efficient State of the Art Rolling Element Bearing Systems

- Integrated Bearing Designs
  - Advanced Bearing Analysis
  - Calculation of Shaft / Gear / Bearing Systems
  - Multi-Body-Calculation
  - Integrated Outer Ring Cooling System
  - Ceramic Rolling Elements
  - Diamond Like Coatings on Rolling Elements
  - Optimized Surfaces
  - Integrated Shaft / Bearing Modules

- 40% Weight & Power Loss Reduction
- Advanced Bearing Cooling Systems
- New Materials, Coatings & Surface Technologies
- Calculation of Shaft / Gear / Bearing Systems
- Multi-Body-Calculation
- Integrated Outer Ring Cooling System
### Transferring the Experience and Technology of Electric Mobility into Aircraft

<table>
<thead>
<tr>
<th></th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schaeffler Group</td>
</tr>
<tr>
<td>2</td>
<td>Motivation</td>
</tr>
<tr>
<td>3</td>
<td>High Efficient State of the Art Rolling Bearing Systems</td>
</tr>
<tr>
<td>4</td>
<td>High Efficient State of the Art e-Mobility Systems and potential MEA Transfer</td>
</tr>
<tr>
<td>5</td>
<td>Summary</td>
</tr>
</tbody>
</table>
Schaeffler Automotive: Covering the full range of powertrain and chassis electrification:

- High Efficient Electromechanical Systems for the Automotive Industry
- Electric Axle Drive
- Hybrid Module
- eWheel
- Hybrid Module
- Active Roll Control System (ARC)
Transfer of the Passenger Car eWheel Technology into Aircraft: eTaxi

Technical data
- Torque: 525 Nm cont. / 850 Nm peak
- Power: 38.5 kW cont. / 60 kW peak
- Weight: approx. 66 kg
- Dimensions: approx. Ø 419 mm x 184 mm
Transfer of the Passenger Car eWheel Technology into Aircraft: eTaxi

Example:

Airbus A320

- 6,799 total deliveries (10,504 family)
- 3,697 firm order backlog (6,132 family)

- Average taxi-time per day & a/c: 95 min
- Average estimated fuel saving per taxiing & a/c: 13 kg/min
- Average estimated fuel saving per day & a/c\(^1\): 1.2 t
- Average estimated fuel saving per year & a/c\(^2\): US$ 200,000

Source: EUROCONTROL, US Department of Transportation, Aircraft Commerce, IATA, Airbus
Note: *As of 30 June 2014

\(^1\) electric power consumption and increased airplane weight not considered  
\(^2\) US$/bbl = 70

The information in this document is the property of FAG Aerospace GmbH & Co. KG and may not be copied or communicated to a third party for any purpose other than that for which it is supplied without express written authority of FAG Aerospace GmbH & Co. KG.
Transfer of the Passenger Car Active Roll Control (ARC) Technology into MEA

Technical description

- Nominal voltage 12V
- Ø90 x 392 mm (without bars)
- Total weight 11.8 kg (w/o bars & cables)
- Nominal 900 Nm, peak 1.200 Nm
- Ramp-up speed 900 Nm at 200 ms
- Torque accuracy at life time 40 Nm (4%)
- ASIL A
Transfer of the Passenger ARC Technology into MEA

Without ARC

General benefits of the ARC

- Significantly improved comfort by
  - reduction of vehicle body roll at cornering
  - reduction of copy movements at poor roads
- Safety improvements due to reduction of over steering
- Improved vehicle dynamics and agility at any speed
- Enables differentiation of platforms from main stream

With ARC

Benefits of the Schaeffler ARC

- CO₂ reduction by 8g /100km\(^{(*)}\) due to power-on-demand
- High actuator dynamics (900Nm / 0,2s)
- High torque accuracy over lifetime
- Plug-and-play – easy handling and assembly
- Maintenance-free

\(^{(*)}\) 0,3l/100km
Transfer of the ARC Technology into Aircraft
Concept Case: Actuation of Slats and Flaps

**State of the Art Hydraulic Flap Actuation System:**

- Rotary or ball screw actuators
- Symmetrical deployment of flap panels
- "Easy to Lock" in case of asymmetry or power loss
- Many mechanical components in the drive system (joints, gearboxes, bearings etc.)
- No individual actuation of each single high lift surface possible
Transfer of the Passenger ARC Technology into Aircraft
Concept Case: Distributed Actuation of Slats and Flaps

**Distributed Electromechanical Actuation System:**
- Elimination of central hydraulic motor and mechanical drive systems
- Individual actuation of each single high lift surface possible, which allows for greater functionality
  - Varying wing profile options lead to improved lift distribution and reduced drag during cruise
  - Vortex decay due to individual deflection
  - Can compensate left / right wing fuel imbalance or OEI conditions
  - Adjustment of the Center of Lift in order to reduce wing bending moment in overload cases

**Electromechanical Roll Control Unit as Flap Actuator**
- Potential use as actuator in distributed flap actuation systems
  - high torque, torque acceleration, and torque accuracy
  - high reliability
  - low weight

The information in this document is the property of FAG Aerospace GmbH & Co. KG and may not be copied or communicated to a third party for any purpose other than that for which it is supplied without express written authority of FAG Aerospace GmbH & Co. KG.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schaeffler Group</td>
</tr>
<tr>
<td>2</td>
<td>Motivation</td>
</tr>
<tr>
<td>3</td>
<td>High Efficient State of the Art Rolling Element Bearing Systems</td>
</tr>
<tr>
<td>4</td>
<td>High Efficient State of the Art e-Mobility Systems and potential MEA Transfer</td>
</tr>
<tr>
<td>5</td>
<td>Summary</td>
</tr>
</tbody>
</table>
Summary

• Advanced mechanical aerospace bearing systems can be leveraged and incorporated in new electromechanical aerospace systems
• Automotive modules such as the eWheel and the ARC present potential for Transfer into MEA
• The eWheel technology is a potential solution for direct electric landing gear drive (eTaxi)
• The ARC system presents a possible option for a distributed flap actuation system

Advanced aerospace bearing systems and new electromechanical systems derived from automotive applications can contribute to more efficient and reliable MEA
Thank you for your attention!