Electric Wheel-Hub-Drive for Aircraft Application – Airbus Trial
Institute of Vehicle Concepts
Dr. Michael Schier
Introduction

DLR – German Aerospace Center

The German Aerospace Center is busy in

Aeronautics

Space

Energy

Traffic

Space agency of the German government
Project management agency
Introduction

DLR – Sites and Employees

- 6,400 staff working in 29 research institutes and facilities at 13 sites
- Offices in Brussels, Paris and Washington
- Partner of
  - European Transsonic Wind Tunnel (ETW)
  - German Dutch Wind Tunnels (DNW)
Electric Wheel-Hub-Drive for Aircraft Application

Content

- Introduction

- Requirements for passenger aircraft autonomous taxiing

- Interfaces to the nose landing gear

- Design of an electric wheel-hub-drive with a high degree of integration

- Test bench results
Electric Wheel-Hub-Drive for Aircraft Application
Requirements for Passenger Aircraft Autonomous Taxiing

- Task: Autonomous taxiing of a passenger aircraft A320
- Driving conditions: TOW 50 tons with 25 km/h
- Maximum power of 50 kW

To be solved by a drive within the NLG:
- Electric machine integrated in the rim of the NLG
- Three switchable gear ratios
- Fed by a fuel cell system

TOW: Take Off Weight, NLG: Nose Landing Gear
- AMM: Towing force = 1.5% of TOW = 7.4 kN
  Break away force = 6% of TOW = 29 kN

- Measured towing force < 7 kN
- Measured break away force = 7 kN (2.6 kNm)

AMM: Aircraft Maintenance Manual, TOW: Take Off Weight
Electric Wheel-Hub-Drive for Aircraft Application

Driving Conditions

<table>
<thead>
<tr>
<th>Variables</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>T: Torque overall</td>
<td>Mass: 50 t</td>
</tr>
<tr>
<td>Ta: Torque for acceleration</td>
<td>Wheel load: 5 t</td>
</tr>
<tr>
<td>Tr: Torque for rolling</td>
<td>Friction coefficient rolling: 0,015</td>
</tr>
<tr>
<td>P: Power overall</td>
<td>Friction coefficient adhesion: 0,6</td>
</tr>
<tr>
<td>Pa: Power for acceleration</td>
<td>Power supply: 50 kW</td>
</tr>
<tr>
<td>Pr: Power for rolling</td>
<td>slope = 0 %</td>
</tr>
<tr>
<td>v_km: velocity in km/h</td>
<td>Maximum Torque = 11 kNm for break away</td>
</tr>
<tr>
<td></td>
<td>Torque = 2,8 kNm for rolling</td>
</tr>
<tr>
<td></td>
<td>Maximum Power = 50 kW</td>
</tr>
<tr>
<td></td>
<td>Maximum Speed = 25 km/h</td>
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</tbody>
</table>
Electric Wheel-Hub-Drive for Aircraft Application, Interfaces to the Nose Leg Gear

Sleeve as the mechanical interface to the axle

Torque link as the mechanical interface to the strut

Rim as the interface to the tyre

Original design of the NLG

Axle and strut imitation

NLG: Nose Leg Gear
Design of the Electric Machine

- **m = 3 phases**
- **p = 8 pole pairs**
- **N = 24 single teeth**
- → 8 delta connected phase systems in parallel
- → winded in one step

The wires of two neighboured nuts are connected in series to get a single tooth coil.

EMF of the 48 wires in 24 nuts

EMF: Electromagnetic Force
Design of the Electric Machine

- 120 ° rectangular form of EMK
- 120 ° rectangular stair form of short current
- 220 Nm, 2000 1/min at gear ratio 1:1

Mounting procedure of the rotor

EMF: Electromagnetic Force

qualitative form of the electromagnetic force

qualitative form of the short current
Design of the Gear System

\[ n_R = \frac{Z_{Ps}}{Z_{Ps}} \cdot n_M + n_M \]

\[ n_R = n_M \cdot \left( -\frac{Z_{Ps}}{Z_{Ps}} + 1 \right) \]

\[ n_M = \frac{1}{n_R - \frac{Z_{Ps}}{Z_{Ps}}} \]

220 Nm, 2000 1/min at gear ratio 1:1
- gear ratio 1:1 for landing
- gear ratio 12:1 for taxiing = 2,6 kNm
- free wheel function

Index: \( n = \) speed, \( z = \) number of teeth, \( M = \) Motor, \( S = \) Sun, \( P = \) Planetary, \( R = \) rim, \( s = \) side of the stator, \( f = \) side of the rim

Motor = planetary carrier

Sun wheel of the stator

Sun wheel of the rim

Sun wheel of the stator

Sun wheel of the rim

Motor = planetary carrier

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Index: \( n = \) speed, \( z = \) number of teeth, \( M = \) Motor, \( S = \) Sun, \( P = \) Planetary, \( R = \) rim, \( s = \) side of the stator, \( f = \) side of the rim
Design of the Gear and Clutch System

- Sun wheel of the stator could be fixed to the stator for a **gear ratio 1:12**

- Rotor = planetary carrier

- Sun wheel of the rim

The sun wheel of the stator could be disconnect from the stator and could be fixed to the rim for a **gear ratio 1:1**

If the sun wheel of the stator is disconnected from the stator and from the rim all parts can **rotate freely**
Verification Tests

Motor test bench

EMC test

Complete drive on roller test bench

Static load test

EMC: Electromagnetic Compatibility
Torque Measurements

Motor overloaded for break away operation

Torque of one motor (at gear ratio 1:1) Torque of one wheel (at gear ratio 1:12)

220 Nm

220 * 12 = 2.6 kNm

(1.3 kNm)

Taxiing on plane surface

Taxiing with slope 1.5 %
2 motors are fed by 2 fuel cell systems with 2 x 25 kW each
Electric Wheel-Hub-Drive for Aircraft Application

Taxiing system shown on ILA 2010

Fuel cell system

Nose landing gear

ILA: International aerospace exhibition, Berlin, Germany, Mai 2010
Taxiing Test in Hamburg-Germany 2011

Thank you for your attention