Ball Bearing Turbocharger – Technology development

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Introduction

Megatrend

CO₂ Reduction / Efficiency Improvement

Drivers

Legislation
95 g/km in 2020

Commercial
Oil price, Cost minimisation

Consumer
Performance and Efficiency

Average CO₂ Emissions

[Graph showing average CO₂ emissions from 2001 to 2011 for different countries]
Development Target

- Emissions target
- Fuel consumption
- CO₂ target
- Target range
- Emissions (HC, NOₓ, particulates)
- Gasoline
- Transmission technology
- Hybridization
- Diesel
Sub-Trends & Main Technologies

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Average CO₂ Emissions
## Sub-Trends & Main Technologies

### Megatrend

| CO₂ Reduction / Efficiency Improvement |

### Subtrends

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<th>Down-Sizing</th>
<th>Down-Speeding</th>
<th>Driving Resistance</th>
<th>Comprehensive Measurements</th>
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### Main Technology

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Forced Induction Concepts

Technology

Drive

Bearing Technology

Forced Induction

Super Charging

Turbo Charging

Mechanical Drive

Electrical Drive

Turbine in Exhaust

Ball Bearings

Ball Bearings

Fluid Bearings

Ball Bearings

Forced Induction = Increased Density of Air
Forced Induction

Gottlieb Wilhelm Daimler (1824 – 1900)

Grandfather Clock Design
[Utilising Gear Driven Precompression]

Patent DRP 34926 1885
Turbocharger - Origin

Exhaust Driven Precompression

Alfred Büchi (1879-1959)

Patent CH 35 259A 1905
Ball Bearing Guided Turbo Charger
Stationary Ball Bearing Benefits

Operational Power Loss of Bearing System

Friction power loss [W] vs. Speed [Hz]

- Plain bearing
  - ~50% reduction

- Ball bearing

Source: Honeywell Turbo Technologies
Transient Ball Bearing Benefits

Source: Honeywell Turbo Technologies

Ball bearing  Plain bearing

Ball bearing  Plain bearing

Ball bearing  Plain bearing

Ball bearing  Plain bearing
Friction Mechanisms

- **Film Bearing**
- **Rolling Bearing**
Flow Regimes

Optimally Flooded

Completely Flooded
Optimal Lubricant Flow

Power Loss [W]

Completely Flooded

Optimally Flooded
Turbo Charger Cartridge Power Loss

- Power loss [W]
- Viscous friction
- Circumferential gap
- Load dependent friction
- Catalogue supplement for fully flooded
- Catalogue speed and viscosity
- Experiment (max)
1-D Fluid Dynamics

1-D Simulation Model

Investigated Geometry

➔ Investigation on Lubricant Availability throughout Operating Conditions
➔ Optimization of Lubricant Supply Paths
Dynamic Bearing Behaviour

Contact Forces

Differential Speed

Contact Pressure

Contact Angle
Ball and Cage Dynamic Behavior
- Contact Forces (vs. Race and vs. Cage)
- Spin/Roll; Ball Excursion, …
BEARINX – Linear Rotor Dynamics

★ Eigenmodes
★ Eigenfrequencies
★ Campbell Diagrams
FEA and Multi-Body-Structure

Pre-Tension Force

Axial Contact

press-fits (inner ring - shaft)

Modal Reduction for the Simulation Platform

Installation Effects
Contact & Centrifugal Forces
Fully Integrated Development Process

- Direct Integration of Nonlinear BEARINX Subsystem into Full System Dynamic Model
- Component Know-How vs. System Know-How
Combined FEM-CFD Analysis
Temperature of Bearing Parts

![Diagram showing temperature distribution in bearing parts](image)

- OR
- IR
- Cage CS
- Cage TS
- Spacer
- Shaft

**Temperature**

**Position in axial direction [m]**

-0.025 to 0.025
Real World Data

**Fuel Economy**
- Friction power loss - 50% in the bearing system
- Fuel consumption - 2.5% (dir. cor. to CO₂ emission)

**Convenience**
- Cold start improvement + 80%
- Drive away torque improved
- Transient response - 41% to boost @ 1500rpm

**Performance**
- Engine rated power increase + 5%
- Engine torque increase + 10% @ ISO soot
- "Kick-down" performance + 2%

**Data source:** Honeywell
## Summary

### Megatrend

**CO₂ Reduction / Efficiency Improvement**

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### Main Technologies

- Forced Induction/Boosting
- Stratified DI / HCCI
- Variable Valve Train
- Low rpm provision of power
- Optimised Transmission e.g.
- Continuously Variable Transmission
- Dual Clutch Transmission
- Turbocharger Ball Bearing
  - ~ + 5% Power increase
  - ~ + 20% Torque increase
  - ~ - 2.5% CO₂ Emission
  - Superior cold start behaviour
  - Superior transient response
We can't solve problems by using the same kind of thinking we used when we created them.

Albert Einstein
1879-1955
[Turbo charging is,] briefly spoken, open the throttle today, are ready to go tomorrow.

Walter Röhrl
Rallye Champion
1980 and 1982