Torque Vectoring for improved vehicle dynamics

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Bosch Engineering GmbH
Bosch Engineering GmbH

- 100% subsidiary of Robert Bosch GmbH
- established in 1999, approx. 1400 employees
- customized solutions based on Bosch products
Torque Vectoring – Actuators

<table>
<thead>
<tr>
<th>Differential</th>
<th>Brake</th>
<th>E-Motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>active differential</td>
<td>brake</td>
<td>electric motor</td>
</tr>
</tbody>
</table>

yaw torque
Contents

unique benefits regarding vehicle dynamics

less compromises

driver

raise performance objectively
Torque vectoring – range of action

- TV electric motors
- TV differential
- TV brake
- TV brake
- ESC
- ESC

understeering

dynamic state of the vehicle

oversteering
Raise the limiting cornering speed

**without torque vectoring - understeering setup -**

- front axle reaches the limit first
- friction potential is **not** utilized completely

**with torque vectoring - neutral -**

- yaw torque reduces lateral slip at front axle
- increased usage of friction potential at rear axle

60
limiting speed

60
limit not reached
**Raise the limiting cornering speed**

**without torque vectoring - understeering setup -**

- Limiting speed: 60
- Front axle reaches the limit first
- Friction potential is not utilized completely

**with torque vectoring - neutral -**

- Limiting speed: 70
- Full usage of friction potential
- Improvement of traction!
Virtual reduction of the moment of inertia

without torque vectoring

with torque vectoring
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raise performance objectively
The compromises in chassis tuning

Torque vectoring alternatives

**lower center of gravity**

**Benefit**
- less load transfer improves traction and agility

**Compromises**
- chassis needs to be adapted
- stiffer springs affect comfort
- less ground clearance

**torque vectoring**

**Benefits**
- torque vectoring does not affect driving comfort
- chassis tuning can be focused more on aspects like comfort and stability, since agility and traction are already improved
The compromises in chassis tuning

Torque vectoring alternatives

**increased camber angle at front wheels**

**Benefit**
- more grip at front axle: increased agility

**Compromises**
- loss of driving stability at high speeds
- no vehicle dynamics control
- tire wear

**torque vectoring**

**Benefits**
- agility improvements are situation dependent (sensor information)
- agility at low speeds, simultaneously stability at high speeds
- adaptive control on dry or wet asphalt and low-μ
Contents

unique benefits regarding vehicle dynamics

less compromises

driver

raise performance objectively
<table>
<thead>
<tr>
<th>Coupé (Bosch Engineering)</th>
<th>Sports car (OEM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>torque vectoring actuator: <strong>4 e-motors</strong></td>
<td>torque vectoring actuator: brake</td>
</tr>
<tr>
<td>total power:</td>
<td>combustion engine power: &gt; 350 kW</td>
</tr>
<tr>
<td>4 x 60 kW</td>
<td>maximum speed: &gt; 250 km/h</td>
</tr>
<tr>
<td>maximum wheel torque: 700 Nm</td>
<td>weight: ca. 1550 kg</td>
</tr>
<tr>
<td>acceleration 0-100 km/h: ca. 7 s</td>
<td>driven wheels: rear axle</td>
</tr>
<tr>
<td>maximum speed: 130 km/h</td>
<td></td>
</tr>
<tr>
<td>weight: 1970 kg</td>
<td></td>
</tr>
<tr>
<td>battery capacity: 45 KWh</td>
<td></td>
</tr>
</tbody>
</table>

Experimental results – TV e-motors and TV-brake

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Speed difference
several attempts to find out
maximum drive-through speed

TV e-motors: 70 km/h
no TV: 66 km/h
Experimental results – brake - skid pad testing

radius = 50m

speed
slowly increasing until the vehicle leaves the circular path

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Steering wheel angle (°)

TV - brake
no TV

lateral acceleration (m/s²)

1 m/s²
Experimental results – brake – race track driving

lap distance: 2.2km
number of laps: 2
lap times reproducibility: < 0.2s
Experimental results – brake – race track driving

- TV brake
- no TV

- Speed level is raised by TV
- Driver brakes earlier due to higher speed
- Earlier on-throttle at corner exit
Experimental results – brake – race track driving

Measured improvement of lap times

Lap time reduction lap 1: 1.1 seconds
Lap time reduction lap 2: 0.95 seconds
Lap distance: 2.2 km

Lap time improvement by torque vectoring strongly depends on:
► Chassis setup of vehicle (this case: understeering)
► Engine capacity: possibility to maintain the speed offset after corner exit (this case: > 350kW)
► Capability of the driver to push the vehicle to the limit (this case: world class driver)

Remember that Nordschleife is 21km...
Conclusion

Torque vectoring

--- An efficient method to improve vehicle dynamics ---

- Improvements in agility, safety, traction
- Chassis tuning without compromising on stability or comfort
- Benefits can be measured objectively
- Proven maturity of brake actuation concept
- Extended opportunities in multi-motor electric vehicles

Thank you for your attention
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