Torsen LSD
in conventional and electric axles
with EPS tuning
(Electric Power Steering)

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Torsen LSD integration challenge topics:

- **New Torsen type D**
  > achieves a new strength / compactness ratio landmark

- **Torsen LSD improves both Performance & Safety**
  > maximize advantages & eliminate disturbances:

  1. "TOC" EPS tuning eliminates torque-steer while ensuring natural steering feel
  2. ESC tuning eliminates initial understeer and boosts corrective yaw moments
  3. Chassis tuning reduces initial understeer as well as unsmooth yaw transients + achieves adequate vehicle natural yaw balance
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Torsen type D: robust & compact

- Larger module & Higher helix angle
- Smaller module & Lower helix angle

Different module and helix angle

Size & Weight Reduction

Small side $F_a \neq F'_a$

Large side $F_a = F'_a$
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Torque Steer Phenomenon

FWD with Torsen LSD

Low Lateral accel & Low Engine Torque:
- Understeering Yaw Moment
- Steering Wheel centering torque

High Lateral accel & High Engine Torque:
- Oversteering Yaw Moment
- Steering Wheel Torque Steer worst case auto steer > hazardous controllability
- TOC > Steering Wheel Return to Center
TOC (Torque Steer Compensation)

Steering
- Steer Speed
- Steer Angle
- Steer Torque

Engine
- Engine rpm or Gear Engaged
- Engine Torque

Vehicle dynamics
- Vehicle Speed
- Wheel Speeds
- Yaw Rate
- Lateral Acceleration
- Longitudinal Acceleration

Steering wheel speed returnability target

Gain = f(steering torque)

Gain = f(Front Wheel Estimated Torque)

Gain = f(Front Wheel Slip)

Gain = f(over or understeer)

Gain = f(lateral accel)

Gain = f(longi accel)

JTEKT Standard Close loop Returnability

Weighted TOC returnability torque to compensate torque steer and keep natural steering feel
EPS & Front Torsen package

- Torque steer is reduced by optimum EPS tuning.
- Torsen distributes torque for improved performance & stability.
- High speed straight line improved steering centering
- EPS & Front Torsen combination provides for Driving Pleasure
- Sporty Driving, sure... ...but also Safety & Comfort.

(*) Limited-Slip Differential
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ESC tuning to the Torsen LSD characteristics

Slight braking to the inside wheels:
Moderate understeering correction: the LSD torque biasing direction towards the cornering external wheel generates a positive controllable tractive yaw moment, as a eLSD would do.

> Decreased braking torque vs. open diff
> Variable yaw amplification effect

Strong braking of the inside wheels:
Strong understeering correction: the LSD torque biasing direction is now to the cornering inside wheel, thereby generating a high grip recovery to the overloaded cornering outside wheel.

> Emergency transient
> Recovers sudden power understeer
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Chassis tuning to the Torsen characteristics

**Throttle On**

**Low $a_y$ & Drive Torque:**
The LSD torque biasing direction is towards the slower rotating cornering inside wheel. As a consequence of the higher torque and the weight shift towards the cornering outside wheel, the inside wheel will speed up.

> Understeering Yaw Moment

**High $a_y$ & Drive Torque:**
The speeding-up of the cornering inside wheel is triggering the torque biasing action to the outside wheel, giving the sensation of LSD response time to the driver, with front axle increased grip and traction performance.

> Oversteering Yaw Moment
Chassis tuning to the Torsen characteristics

Throttle Off

Inadequate chassis tuning to LSD locking characteristics

Open Diff

Torsen

Time

Initial grip gain + stabilising yaw moment

Countersteer

Throttle-off:

The higher coast torque is biased towards the faster rotating outside wheel while increasing lateral grip by avoiding the onset of inside wheel reverse slip

> Tack-in followed by Understeering Yaw Moment
Obstacle avoidance improved agility & stability

Phase 1
Reactivity to steering input

Phase 2
Yaw reaction following phase 1

µx
µy
+ initial grip

µx
µy

Improved agility

Improved stability
Front Torsen improves both FWD & hang-on AWD performance

- In narrow corners, the front axle has the highest positive tractive yaw moment generating potential

  - **Traction**
    F/R ideal torque distribution ≈ F/R weight distribution (typically ~60/40%) but this causes unwanted power understeer!

  - **Cornering performance**
    F/R ideal torque distribution is rear-biased but causes increased rear wheel slip and is detrimental to traction

- With Front Torsen LSD:
  - **High traction**
    - Front biased F/R torque distribution
    - Torque biasing to cornering outside wheel
  - **Cornering performance**
    - Front axle positive tractive yaw moment
    - Higher rear axle side slip angle with low torque >>> less power understeer
Thank you for your attention

Danke für Ihre Aufmerksamkeit

Grazie per la Vostra attenzione

Merci pour votre attention

ご清聴、ありがとうございました