



ZEROSHIFT

**The development of an instant
gearshift system**

Adam Huckstep

Chief Engineer - Zeroshift

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PRESENTATION OVERVIEW

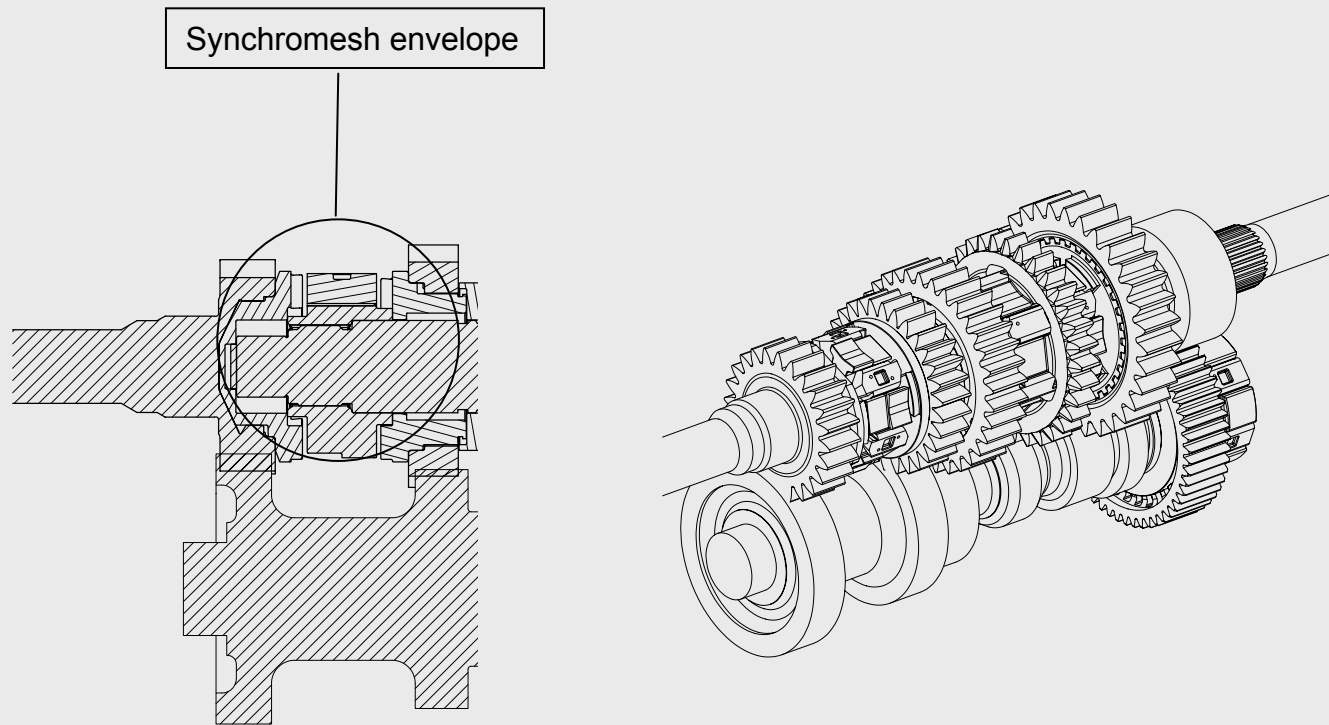
- **Concept**
- Considerations for an instant gearshift
- Development
- System Calculations
- Managing a 'Zeroshift'
- Data collection and analysis
- Benefits

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CONCEPT

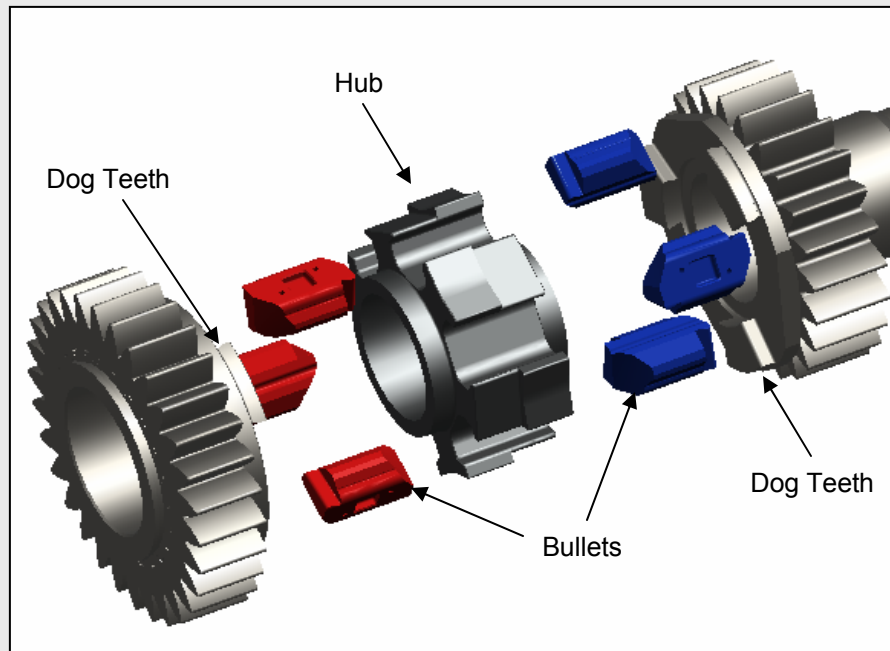


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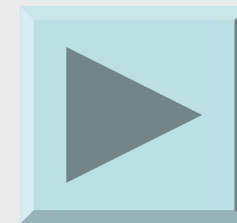
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CONCEPT



PLAY ANIMATION



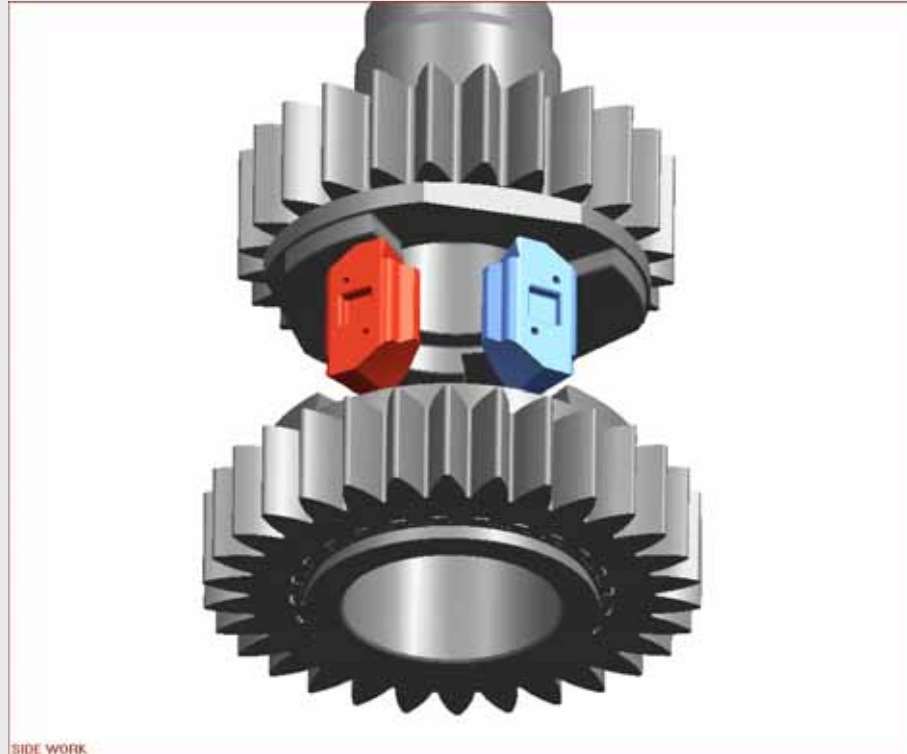
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CONCEPT

NEUTRAL



SIDE WORK

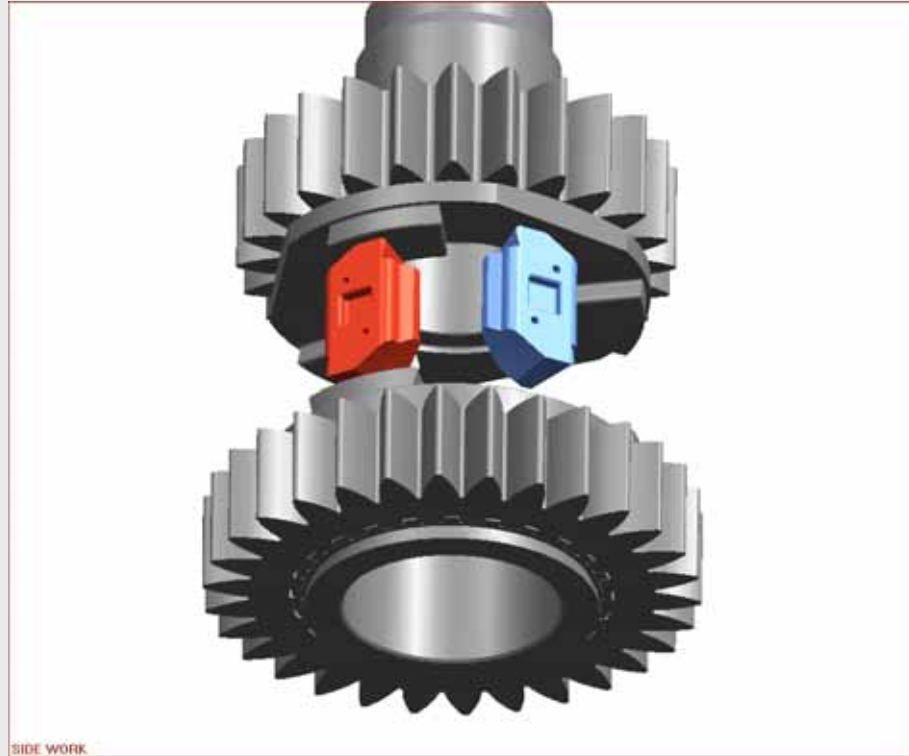


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CONCEPT



SIDE WORK



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CONCEPT



SIDE WORK

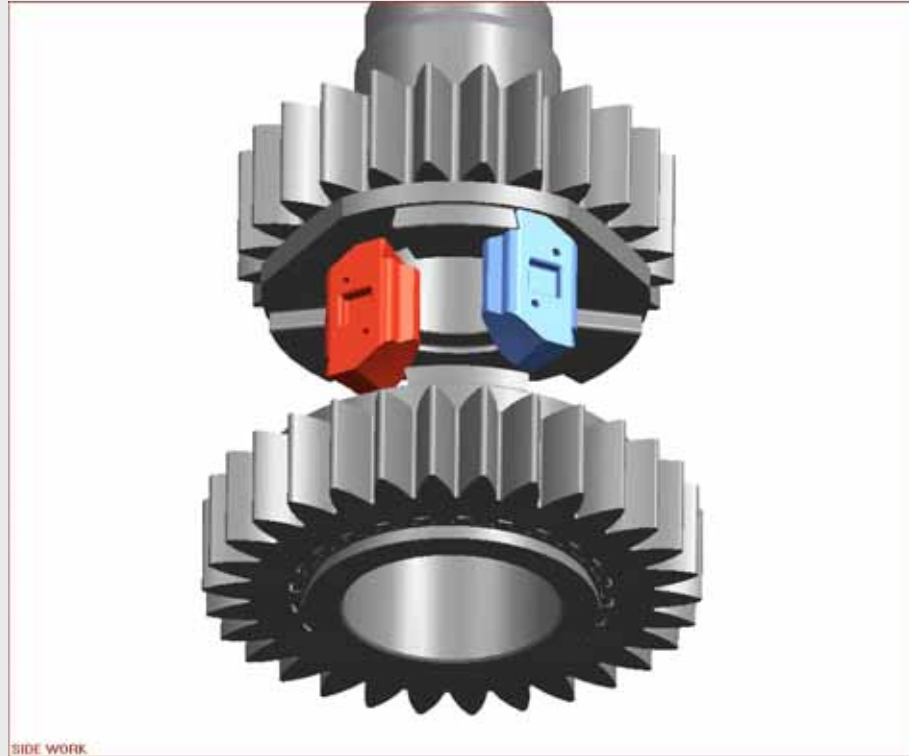


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CONCEPT



SIDE WORK

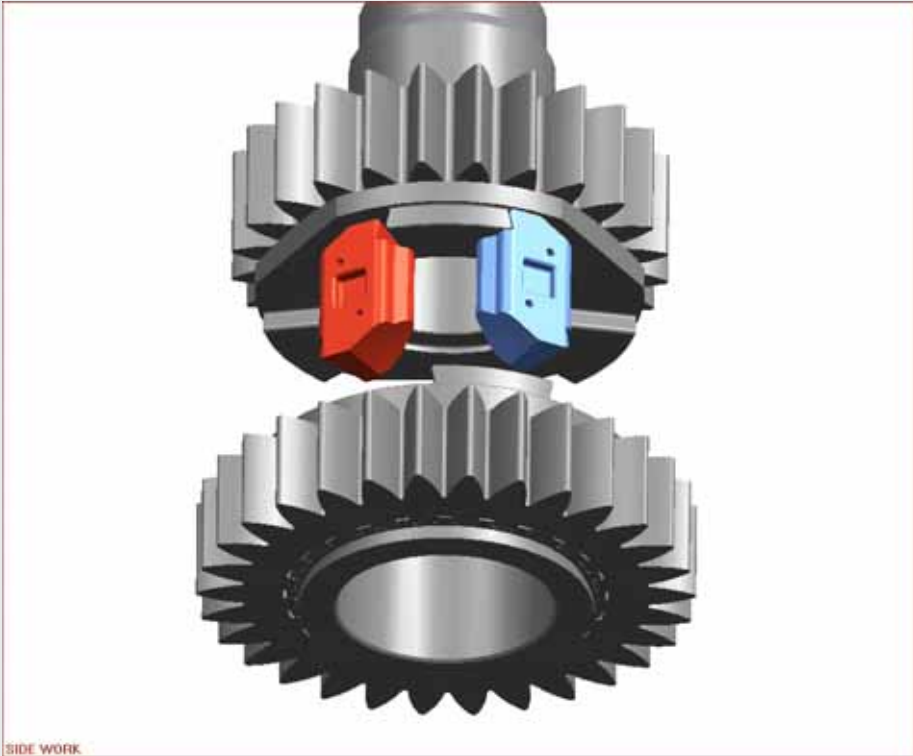


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CONCEPT



SIDE WORK



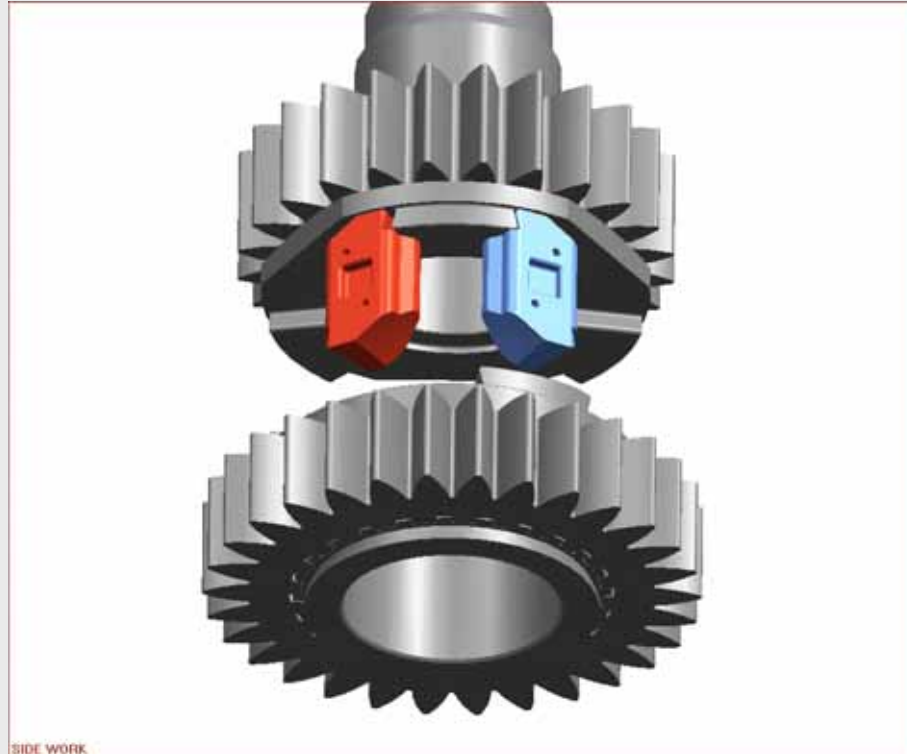
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CONCEPT

1ST GEAR ENGAGED



SIDE WORK

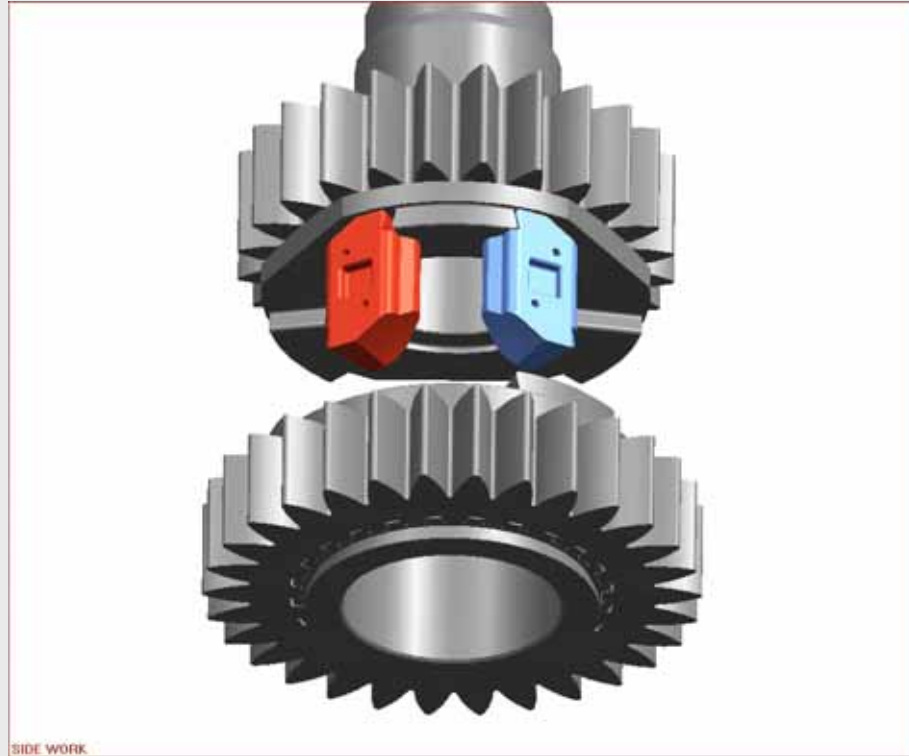


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CONCEPT

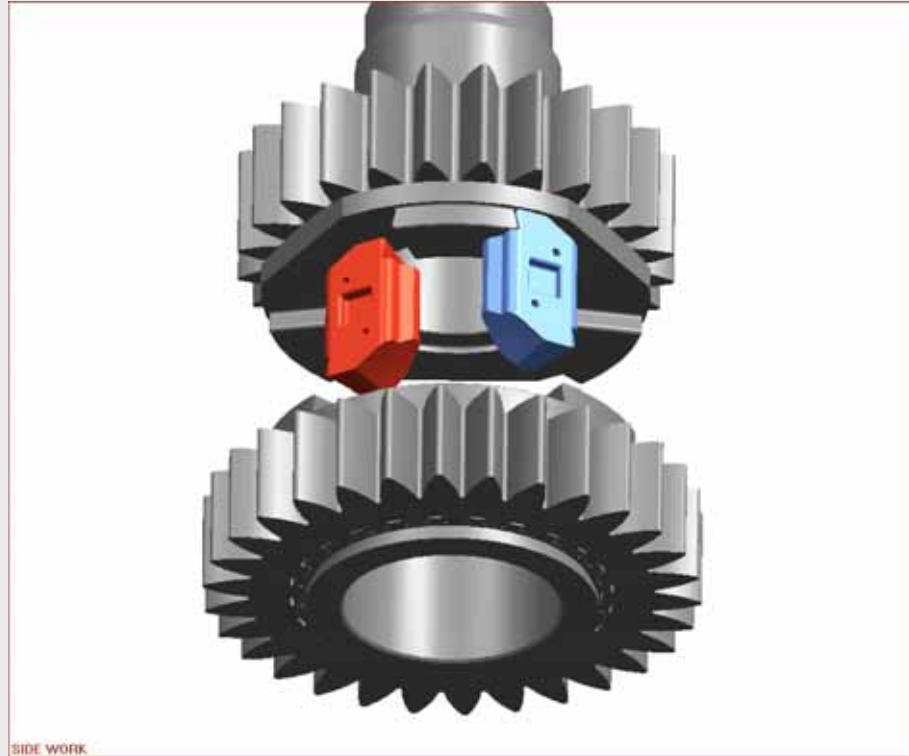


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CONCEPT



SIDE WORK

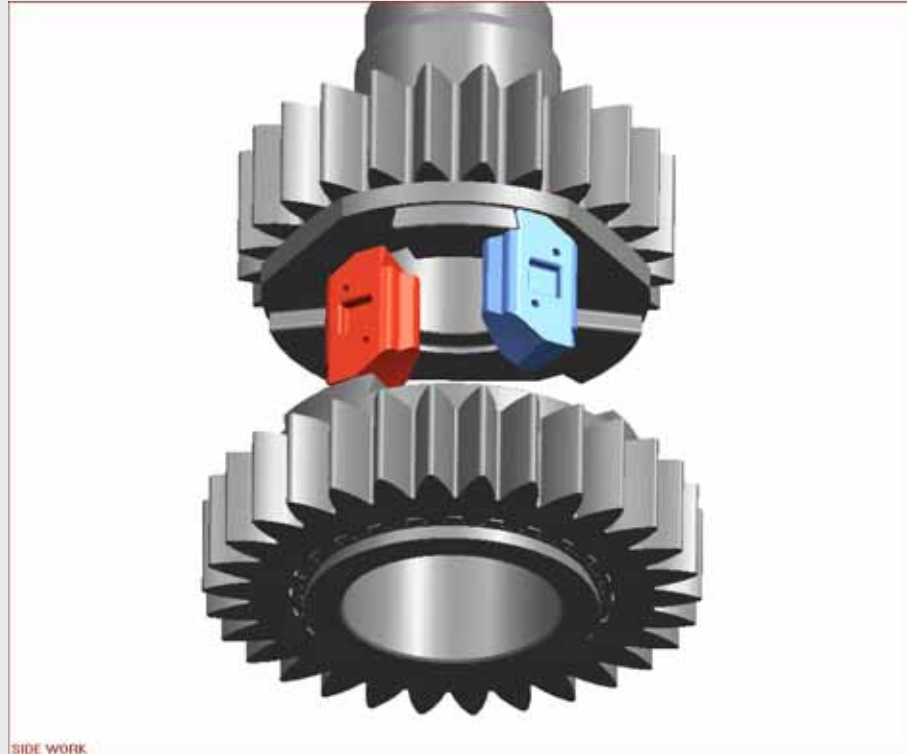


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CONCEPT



SIDE WORK

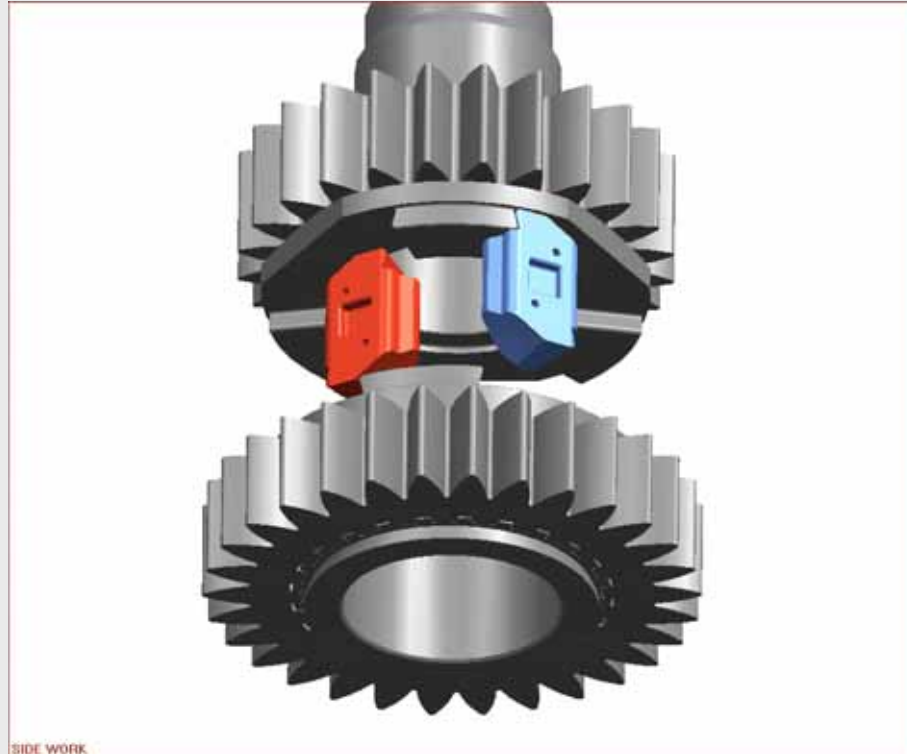


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CONCEPT



SIDE WORK

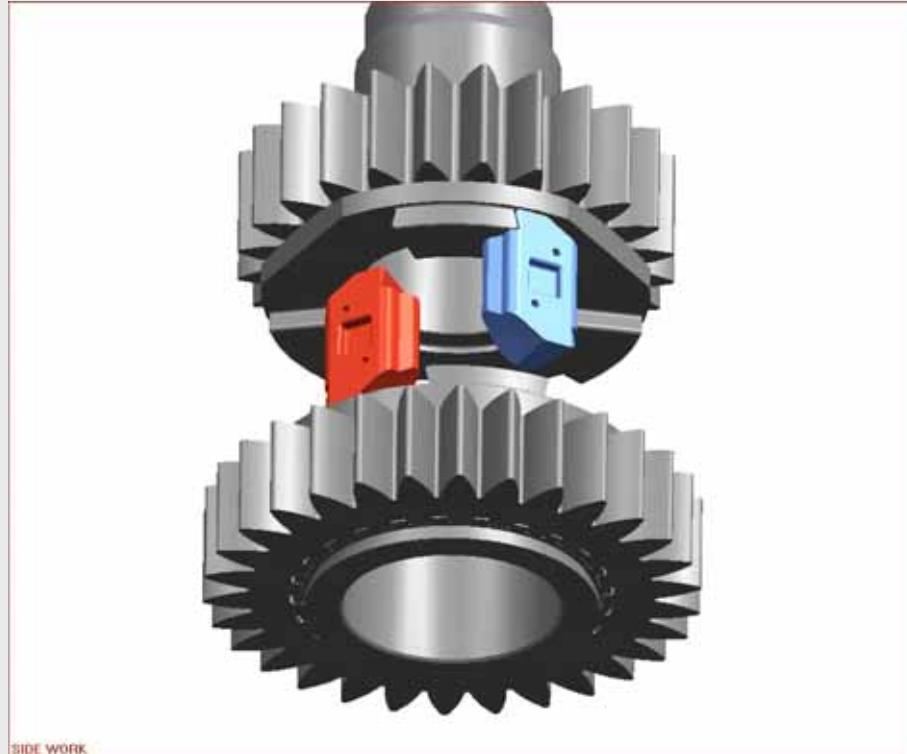


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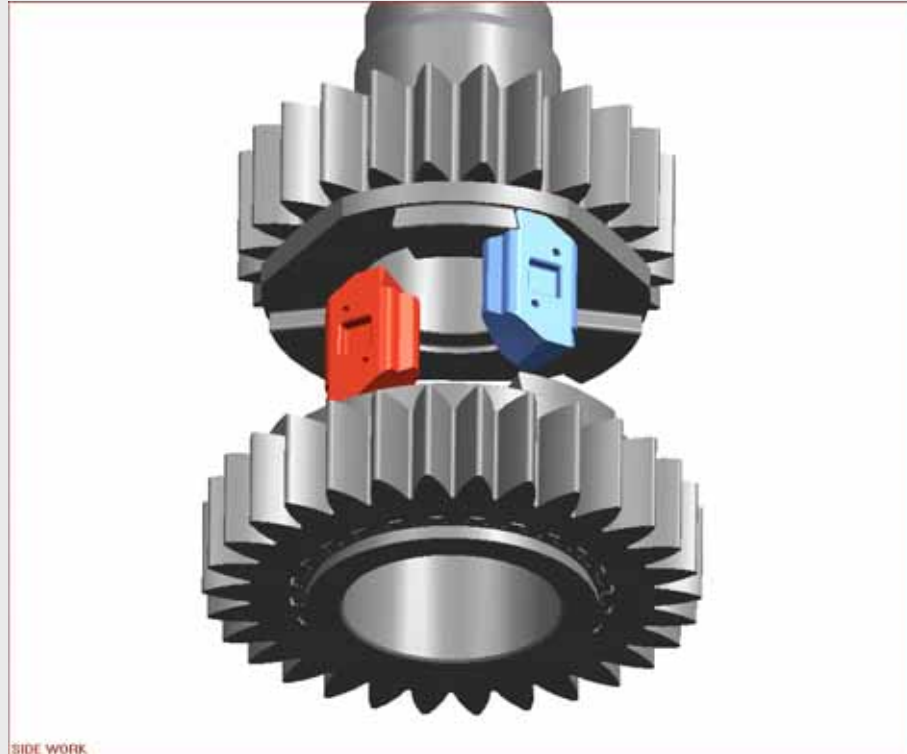


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CONCEPT



SIDE WORK

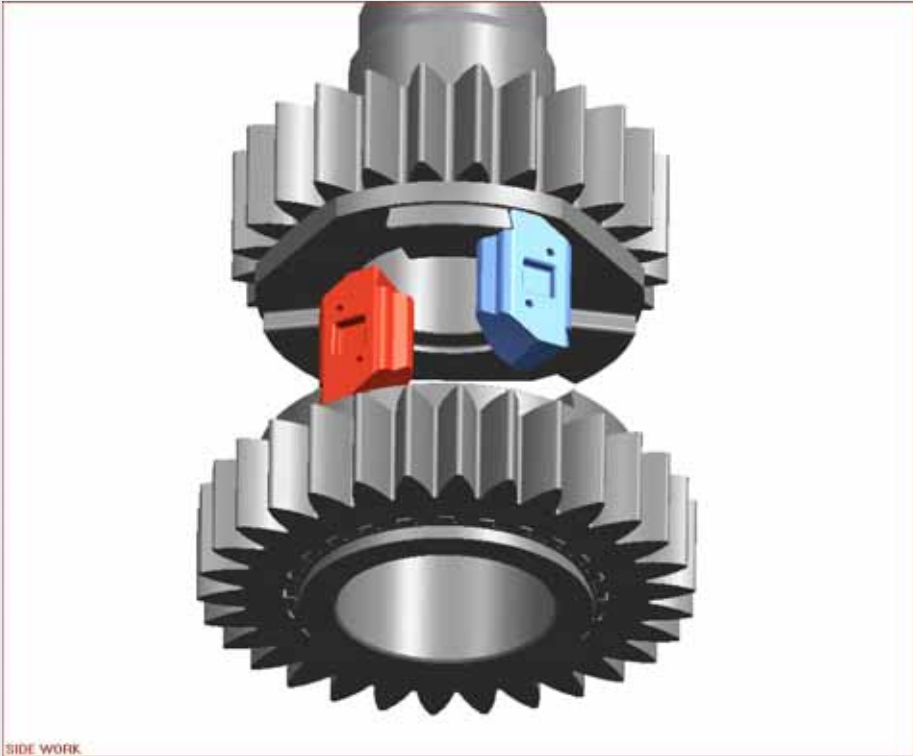


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CONCEPT



SIDE WORK

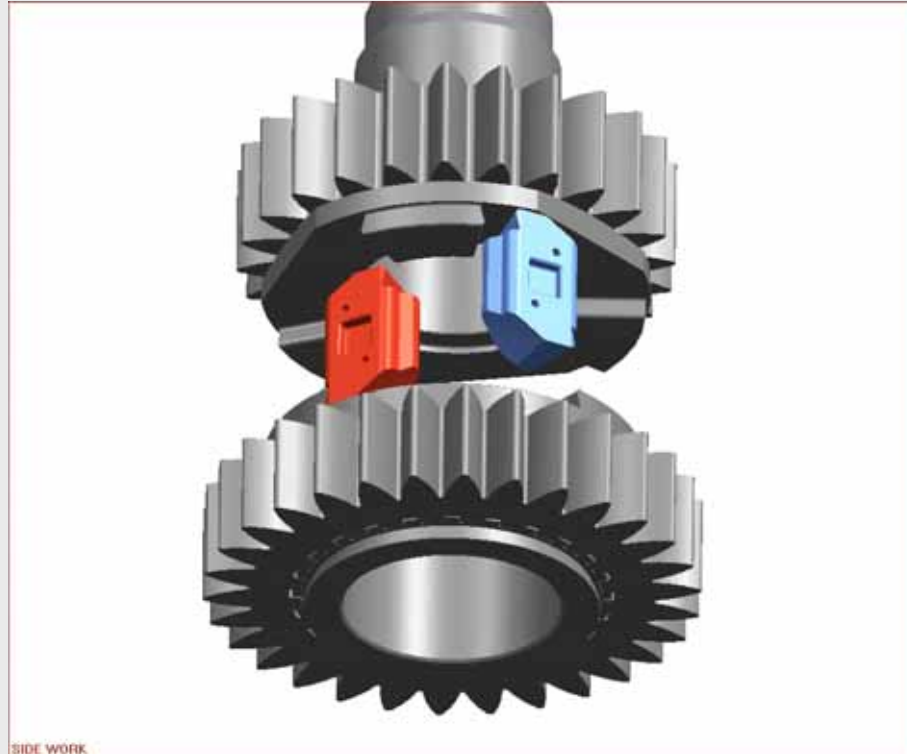


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CONCEPT



SIDE WORK



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CONCEPT



SIDE WORK



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CONCEPT



SIDE WORK

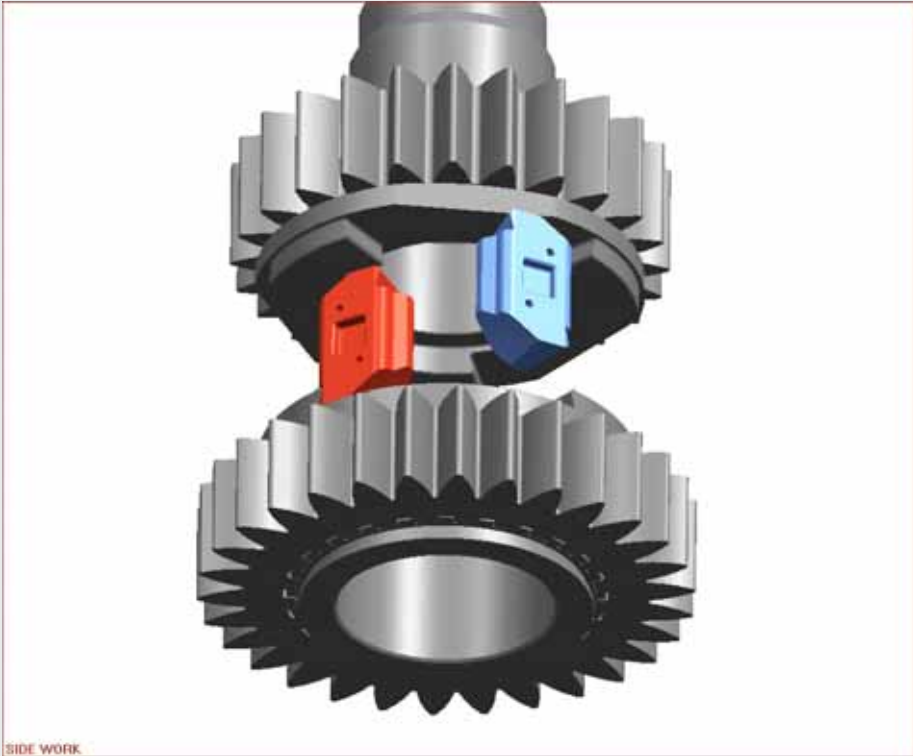


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CONCEPT



SIDE WORK



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CONCEPT



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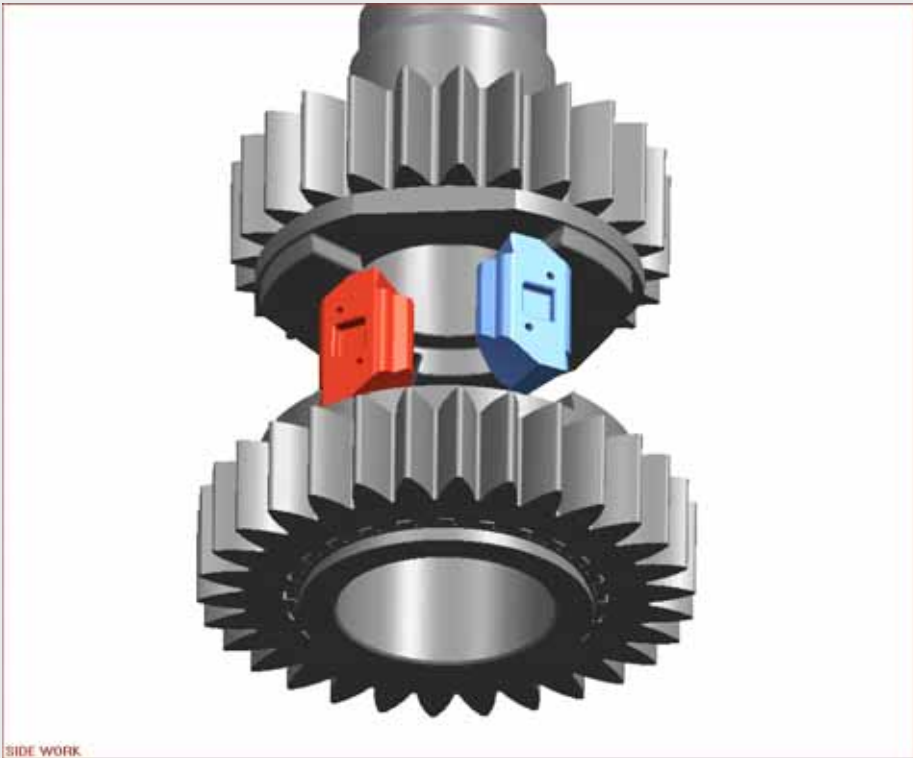


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CONCEPT



SIDE WORK



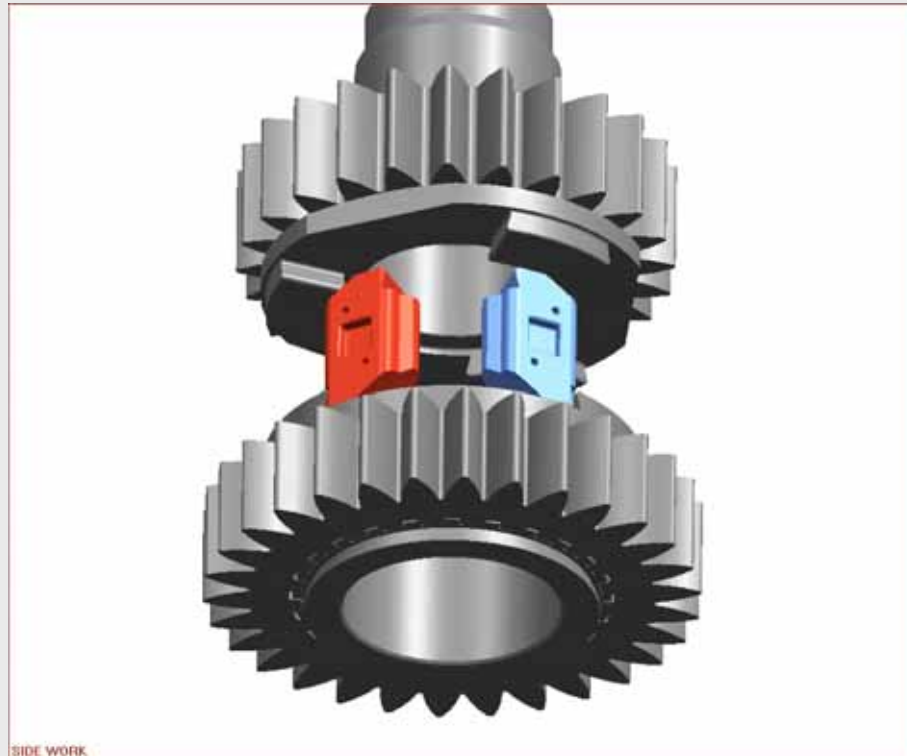
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CONCEPT

2ND GEAR ENGAGED



SIDE WORK



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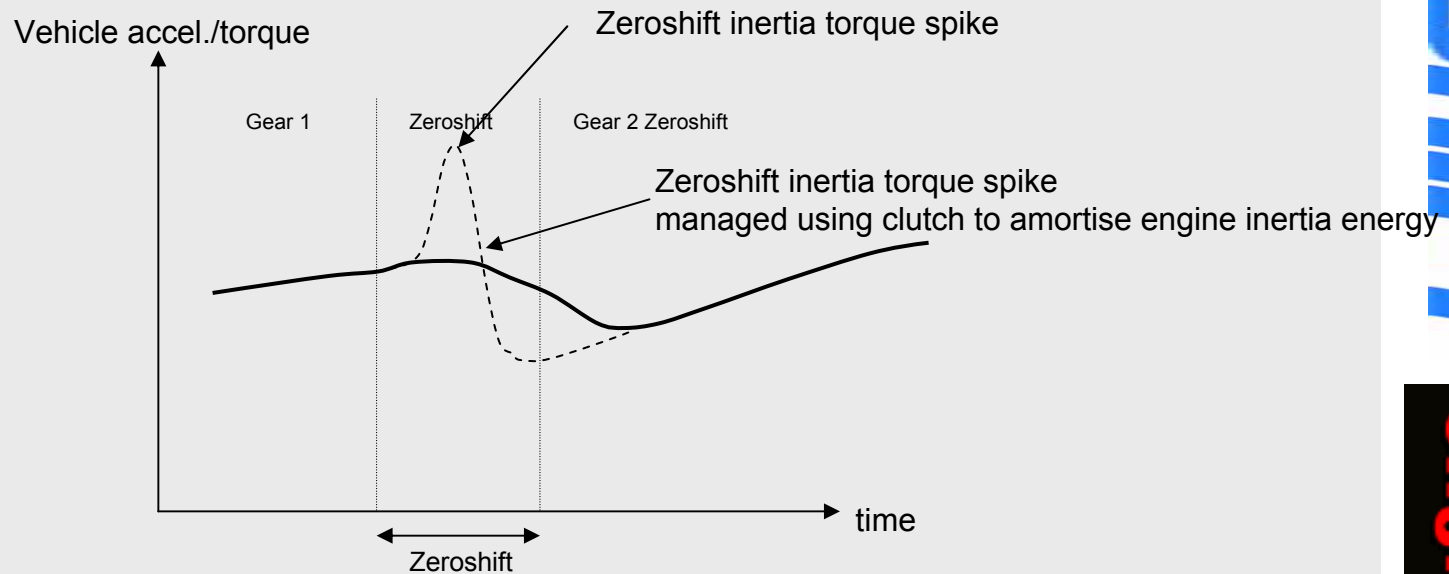
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CONSIDERATIONS FOR INSTANT GEARSHIFT

- Shift event



- Engine inertia torque
- Decelerating engine on up-shifts
- Accelerating engine on down-shifts
- Driveability and shift quality

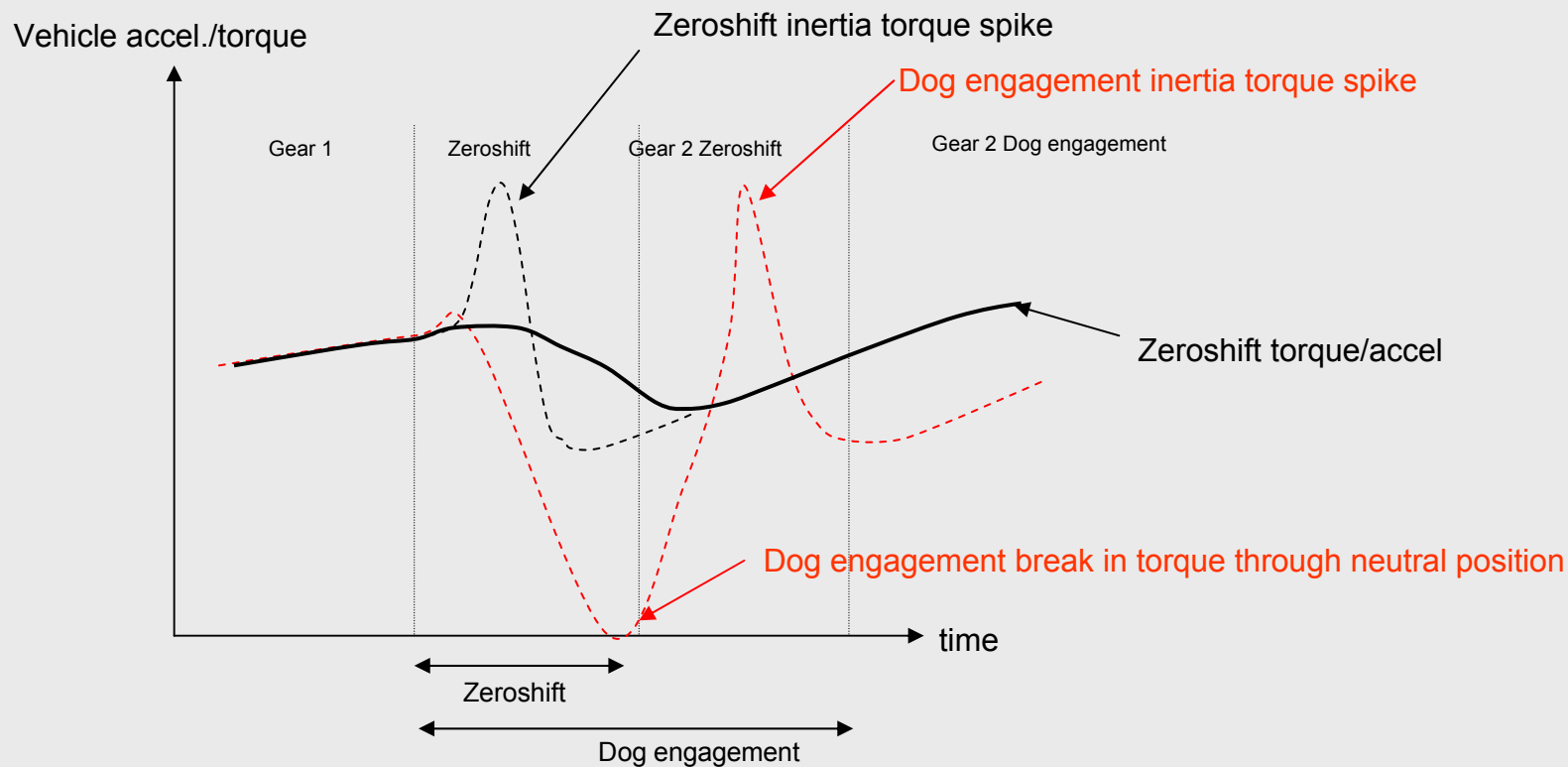
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CONSIDERATIONS FOR INSTANT GEARSHIFT

- Comparison to other clutchless dog engagement systems



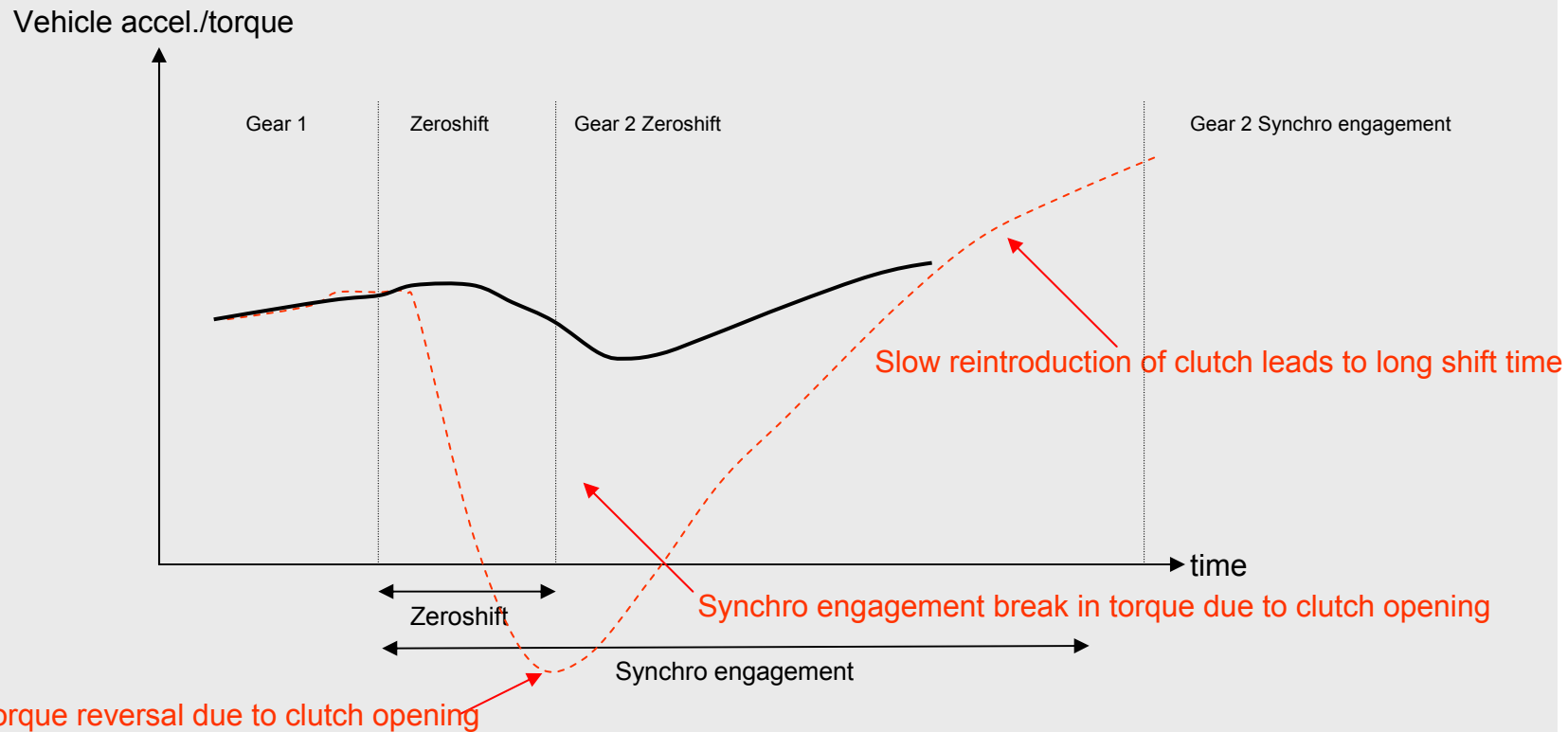
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CONSIDERATIONS FOR INSTANT GEARSHIFT

- Comparison to synchro engagement systems



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DEVELOPMENT

Mule transmission

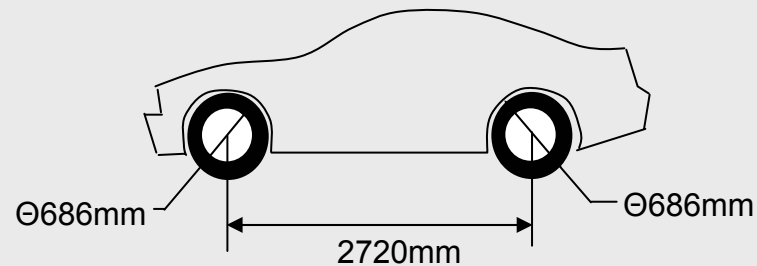
- Tremec T5 5 speed



Development car

Ford Mustang V6 4.0L

Configuration	V6
Output	210 bhp @ 5300 rpm .7355 = 154 kW
Torque	240 lb.ft (claimed) @ 3500 rpm x 1.356 = 325 Nm
Curb weight	1500 kg
HP/Curb weight	140 bhp per tonne
Length	4765 mm
Height	1384 mm
Width	1877 mm



New Zeroshift Transmission ZS01

6-speed sequential AMT

Based on Tremec T56

Single-plate dry clutch

Closed loop electro-mechanical clutch control

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DEVELOPMENT

Controls and Electronics

- Zeroshift TCU (Zeroshift hardware and software)
- Zeroshift transmission control algorithms
- Electro-pneumatic actuation (electro-hydraulic and electric shift systems in development)
- Spark cut
- High-speed (kHz) datalogging of transmission internal speeds, driveline torques and vehicle CAN data

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SYSTEM CALCULATIONS

Transmission Ratios

1 st gear	= 3.75:1
2 nd gear	= 2.19:1
3 rd gear	= 1.41:1
4 th gear	= 1.00:1
5 th gear	= 0.72:1
Rev	= 3.55:1
Rear Diff	= 3.31:1

Car specification

Ford Mustang	4.0 L V6
Configuration	V6
Output	210 bhp(154kW) @ 5300 rpm
Torque	240 lb.ft (325Nm) @ 3500 rpm
Kerb weight	1500 kg
Length	4765 mm
Height	1384 mm
Width	1877 mm

Loadings

•Example in 1st gear

Torque through 1st gear set of bullets -> c.1220Nm

Force on 1st gear bullets - > c. 44kN

Due to machining and tolerances of the components involved drive will temporarily be taken up by 1 bullet until it deflects enough for the loading to be spread across the remaining bullets.

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MANAGING A 'ZEROSHIFT'

- Shift event
 - Engine management (inertia, torque)
 - Clutch strategy (pre- and post-shift)
 - Post-transmission damping
- Accelerating upshifts, decelerating downshifts
- Accelerating downshifts
 - (torque roll-off required)
- Decelerating upshifts
 - Throttle blip required
- Shift quality refinement
 - Shift Mapping
 - Closed/open loop clutch control
- NVH

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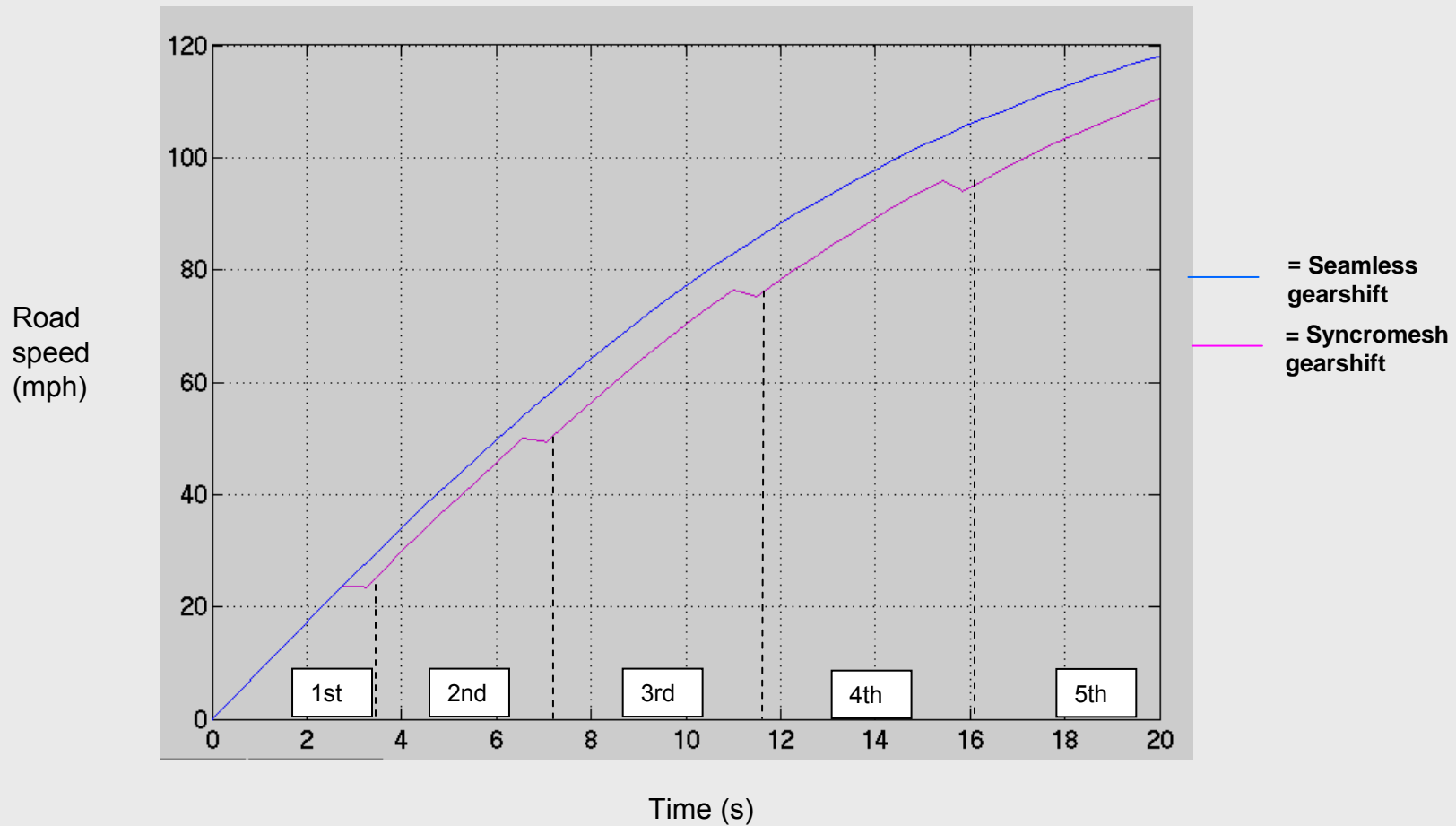
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DATA COLLECTION AND ANALYSIS

Road speed vs. time



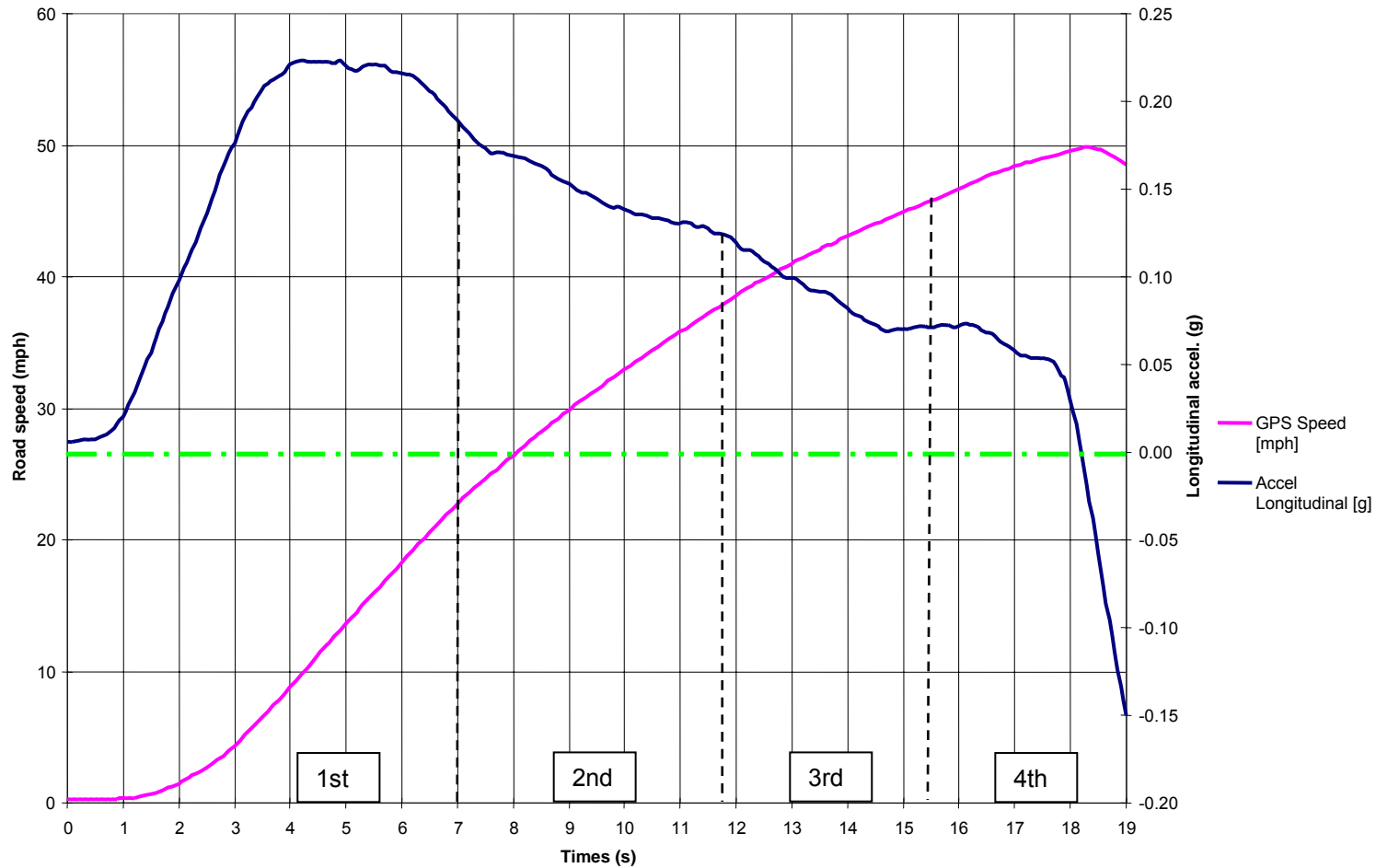
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DATA COLLECTION AND ANALYSIS

Zeroshift Ford Mustang



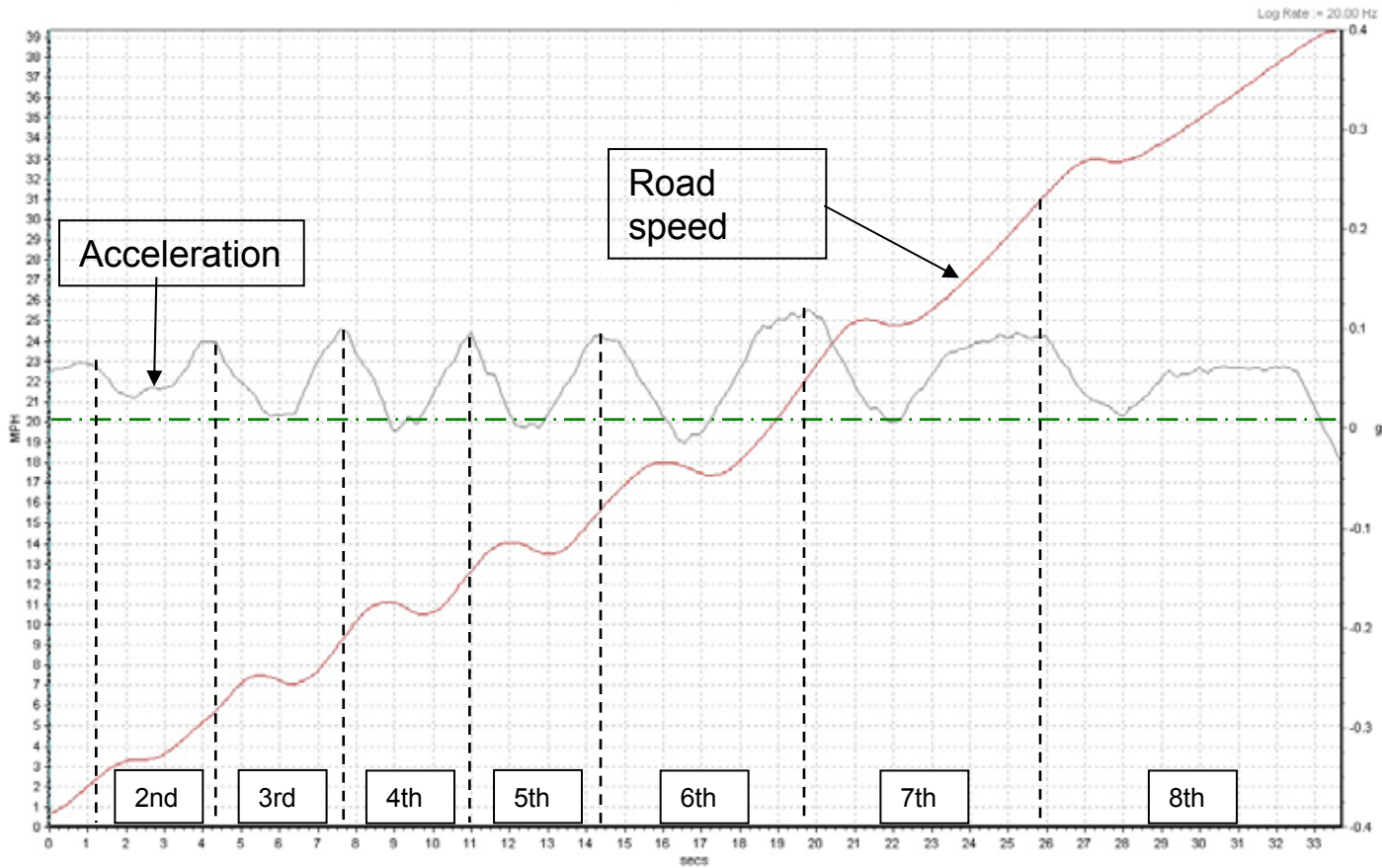
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DATA COLLECTION AND ANALYSIS

HGV Scania



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- **Benefits**

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BENEFITS

- Performance and acceleration improvement – no coasting/torque reversal on upchange
- Shift quality – no torque reversal ‘head-nod’
- Weight saving over competing technologies
- Simple and inexpensive to manufacture compared to competing technologies
- Transmission efficiency
- Packaging advantage – no increased packaging volume required over conventional synchronised manual
- Transient emissions improvement and fuel economy

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QUESTIONS

- Questions ?

www.zeroshift.com

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SYSTEM CALCULATIONS

Angular Impulse from an instantaneous gearshift

$$E_k = \frac{1}{2} I_m \omega^2$$

$$\underbrace{T_o t}_{\text{Angular impulse}} = \underbrace{I_m \omega_f - I_m \omega_o}_{\text{Angular momentum}}$$

Torsional stiffness

$$k = \frac{G \pi D^4}{32L}$$

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SYSTEM CALCULATIONS

Vehicle Resistance

Tractive resistance = Rolling resistance + Aerodynamic drag

$$F_w = F_{RO} + F_L$$

$$F_{ro} = f \cdot m \cdot g$$

$$F_L = 0.5(\rho)C_D(A)v^2$$

F_{RO} =Rolling resistance

F_L =Aerodynamic drag

Inertias

- Managing engine and driveline inertia during a 'Zeroshift'.

$$F(s) = \underbrace{M \cdot a(s)}_{\text{Vehicle mass}} + \underbrace{I_f \cdot \frac{a(s)}{R_f^2}}_{\text{Front rotating masses}} + \underbrace{(I_r + I_m \cdot G_r^2) \cdot \frac{a(s)}{R_r^2}}_{\text{Powertrain}} + \underbrace{\frac{1}{2} \cdot \rho \cdot A \cdot C_D \cdot v^2}_{\text{Aerodynamic drag}}$$

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