ECONOMIC ANALYSIS AND POSSIBILITIES OF APPLICATION TO BEV GEARBOXES

Eachen, April 08th, 2025

Final Workshop

Lateana – CRF

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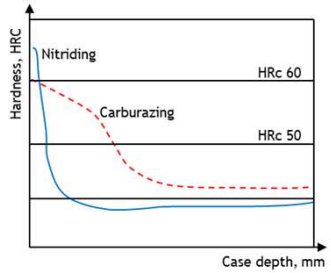
General Overwiev

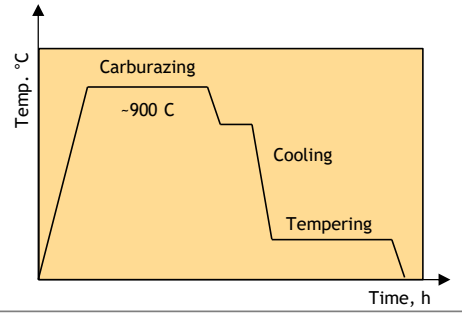
- Heat Treatment: Carburazing VS Nitriding
- Machinability assessment
- Process Comparison
- Overview of costs assessment
- Possibilities of application to BEV gearboxes

Machinability assessment

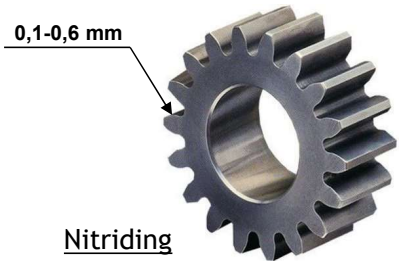
- Heat Treatment: Carburazing VS Nitriding

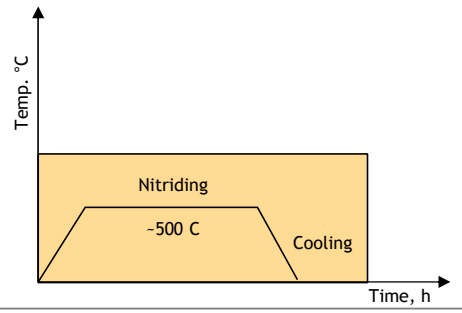


Parameter	Carburizing
Maximum temperature reached	~ 850-950°C
Processing time	5-20 hours (depending on depth)
Achieved hardness (HV)	~550-700 HV (martensite and carbides)
Geometrical deformation	High (often requires post-treatment grinding)
Furnace Investment Cost	€€ (Medium-High)
Energy cost treatment	High (due to high temperatures and quenching)
Heat treatment	Uses a Carbonaceous environment. Carbon diffuses onto the surface.



Parameter	Nitriding
Maximum temperature reached	~500-600°C
Processing time	20-100 hours (depending on depth)
Achieved hardness (HV)	~900-1100 HV (nitrides layer)
Geometrical deformation	Minimal (can be applied to finished parts)
Furnace Investment Cost	€ Low
Energy cost treatment	Lower (due to lower temperatures and absence of quenching)
Heat treatment	Uses nitrogen environment. Nitrogen is diffuses onto the surface.





Machinability assessment

- Rough and Finishing Machining
  - For machinability evaluation (four steels considered)
  - Pre HT: Sintered carbide inserts (low-medium hardness)
  - Post HT: CBN inserts (high hardness)*

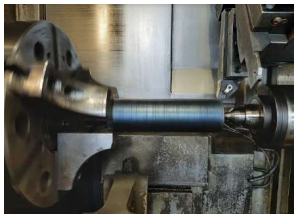
- Test: external turning test (ISO 3685:1993)
  - V15 index
  - Taylor curves
  - Wear curves

Steel Grade	Billet Dimension	As supplied	Heat Treatment	Treatment conditions
27MnCr5	Ø 60 mm L 500 mm	Isothermal annealing	LPC and High Pressure Gas Quenching.	Vacuum Heating: 950°C Carburizing: 950°C Final diffusion Quenching
42CrMoBi4	Ø 60 mm L 500 mm	Quenched and Tempered	Nitriding	Nitriding 450 C Cooling controlled

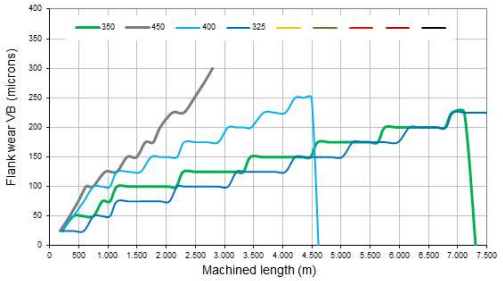
**fine work is not necessary for Nitride process*

Machinability assessment

Rough and Finishing Machining

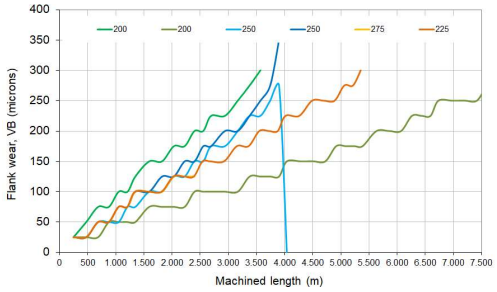


Flank wear evolution curves - 27MnCr5
(range cutting speeds from 325 m/min to 450 m/min)



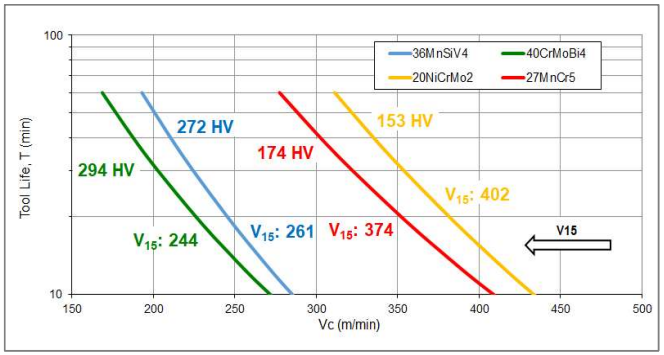
Chip morphology generated during external turning - 27MnCr5

Tool wear evolution curves - 40CrMoBi4
(range cutting speeds from 200 m/min to 275 m/min)



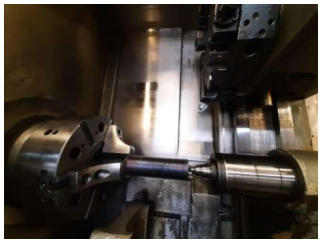
Chip morphology generated during external turning - 40CrMoBi4

Machinability Taylor curves for the four steels



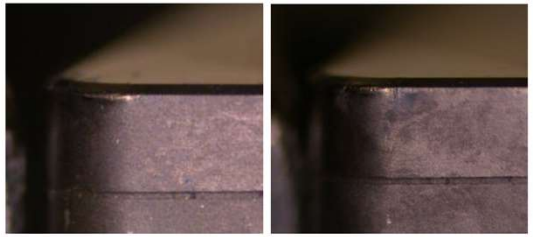
Machinability assessment

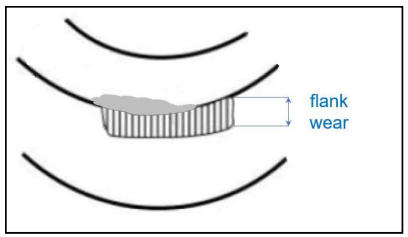
Rough and Finishing Machining



Flank wear at the initial (left) and final (right) turning step for 27MnCr5

Flank wear at the initial (left) and final (right) turning step for 40CrMoBi4

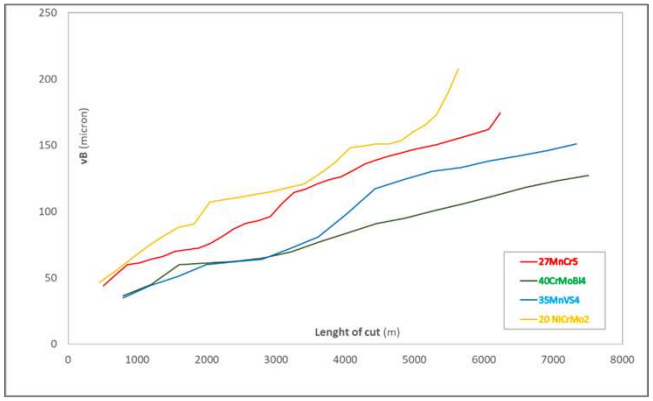




Cutting operation	External turning
Coolant	Dry cutting (no coolant)
Cut depth, a_p	2 mm
Feed, f	0.3 mm/rev
End test criterion	VB=300µm or tool death

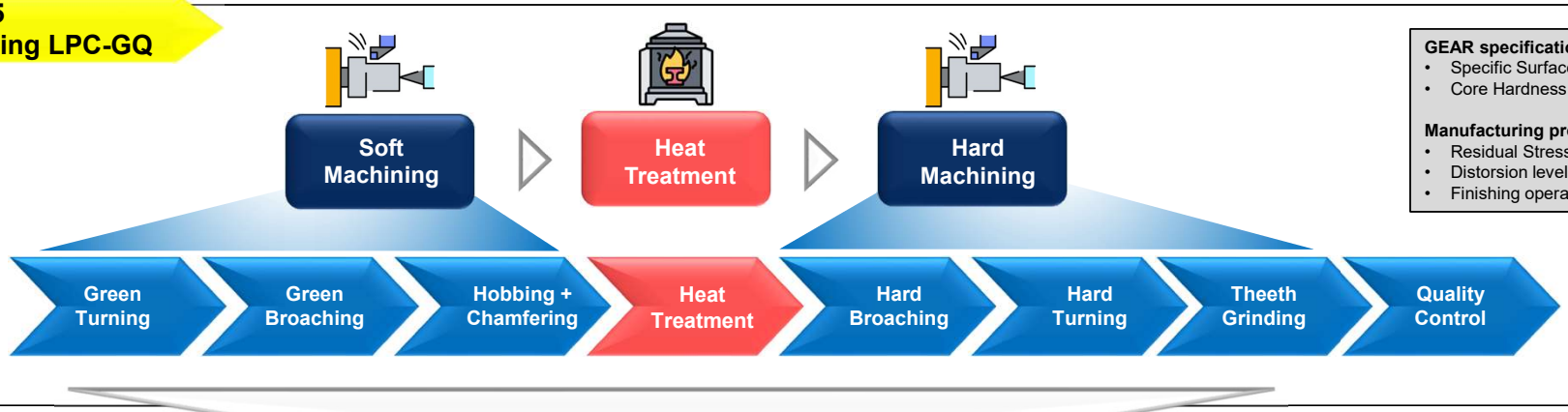
Cutting tool type	Sintered carbide
Tool manufacturer	SANDVIK
Cutting tool code	CNMG 120408 PM 4015 (GC4015)
Edge radius	0.8 mm
Coating	TiCN-Al2O3-TiN, 14µm

Comparison between the insert flank wear progression vs heat treated steel grade



Process Comparison

27MnCr5
Carburizing LPC-GQ



GEAR specification
- Specific Surface hardness (59HRC)
- Core Hardness (330-420HV)

Manufacturing process point of view
- Residual Stress after HT
- Distorsion level after HT
- Finishing operation after HT

40CrMoBi4
Nitriding

GEAR specification
- Specific Surface hardness (550-600 HV)
- Core Hardness (300-330 HV)

Manufacturing process point of view
- Lower distortion after HT
- Finishing operation before HT due to low hardening depth after HT

No need turning phases after HT process

Overview of costs assessment

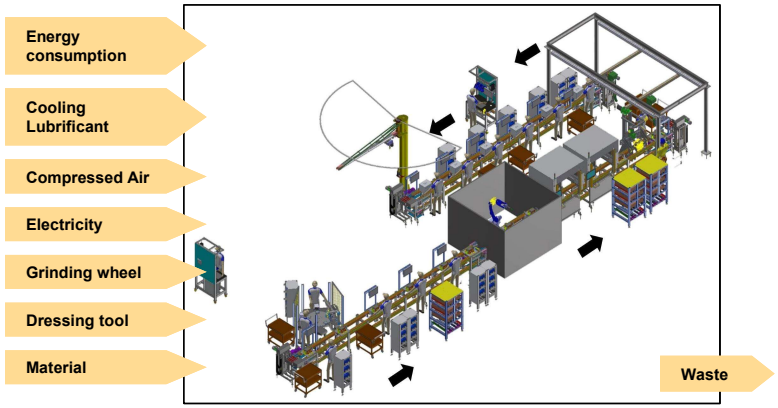
- **Operating costs**

Conventional Scenario

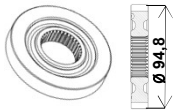
27MnCr5

OP310	Green Turning
OP320	Green Broaching
OP330	Hobbing + Chamfer
OP340	Heat Treatment
OP350	Hard Broaching
OP360	Hard Turning
OP370	Theeth Grinding
OP380	Quality control

Production line



Example of cost items



Mechanical machining for gears	
Management Costs	Oil
	Storage and disposal of machining waste
	Tools
Energy Consumption	Machine
	Utilities
Technical gallery management	Lubricant centralized plant management
	Air Conditioning

Alternative Scenario

40CrMoBi4

OP310	Hard Turning
OP320	Hard Broaching
OP330	Hobbing + Chamfer
OP340	Heat Treatment
OP350	Quality control

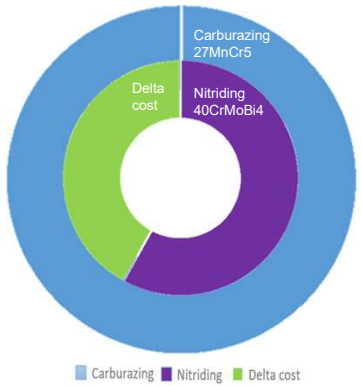
Overview of costs assessment

- **Operating costs**

Carburazing ➡ Nitriding

less expensive of ~ 42% than Caburazing process

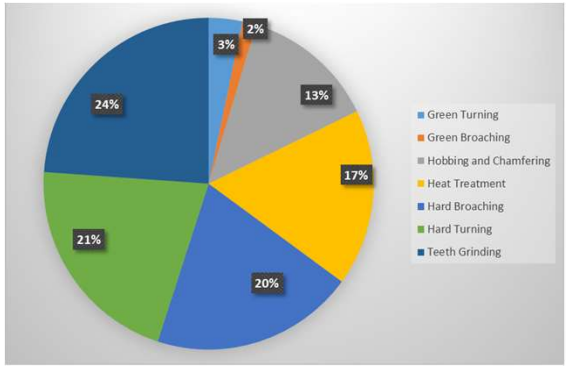
Cost per piece comparison



- hypothesis of one year production for 500k gears
- equal working conditions in two processes compared

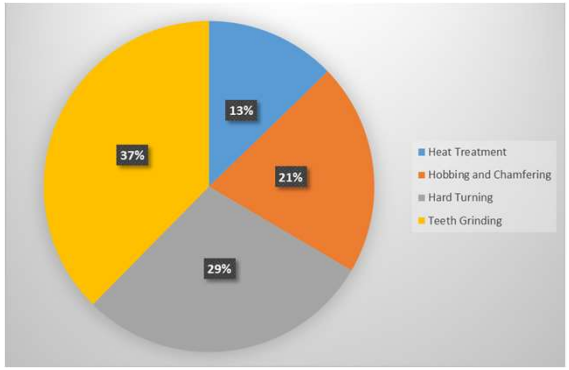
Cost distribution for producing one piece

Carburazing- 27MnCr5



Cost distribution for producing one piece

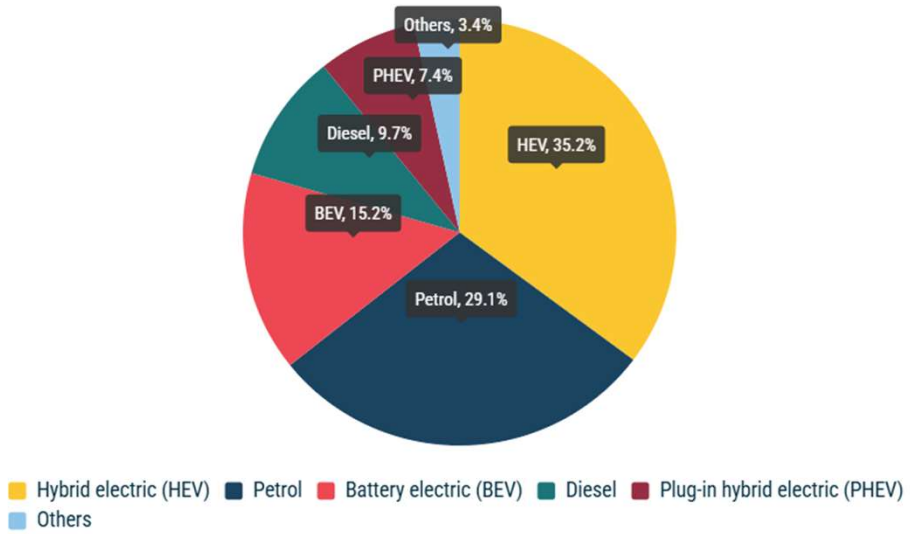
40CrMoBi4 - Nitriding



Application to BEV gearboxes

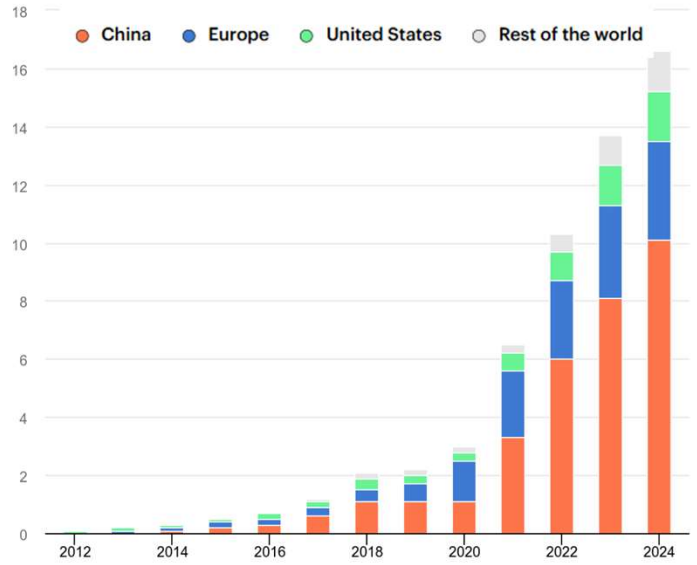
- General overview

EU car trend by power source



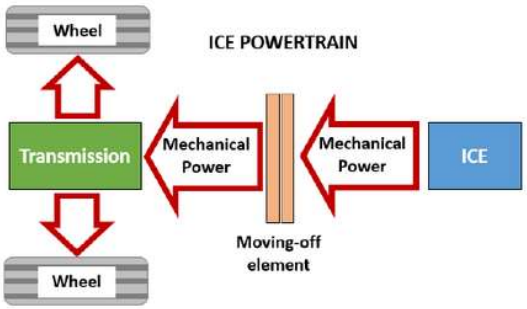
https://www.acea.auto

EV Car sales worldwide by region

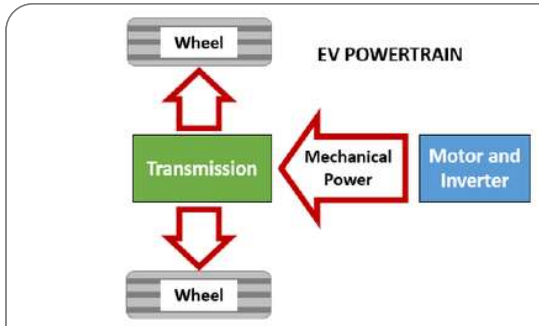


https://www.iea.org/

- **Possibilities of application to BEV gearboxes**

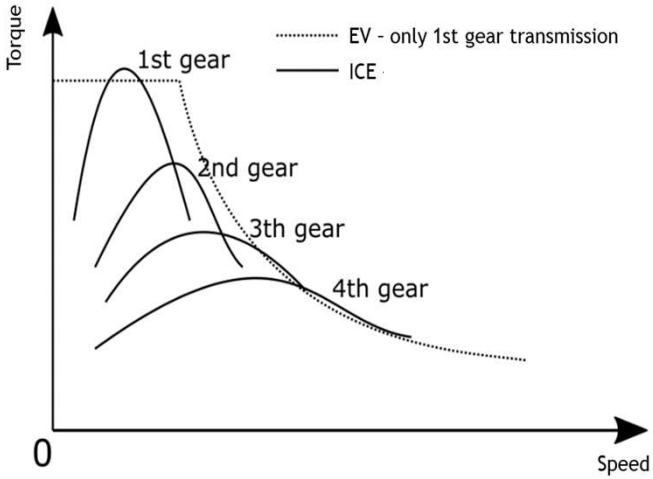


- Multispeed transmission
- Provide high number of gear ratios
- Adapting output torque engine
- Clutch/torque converter (system for start-stop due to ICE characteristic)
- Reverse (backwards) with same engine rotating

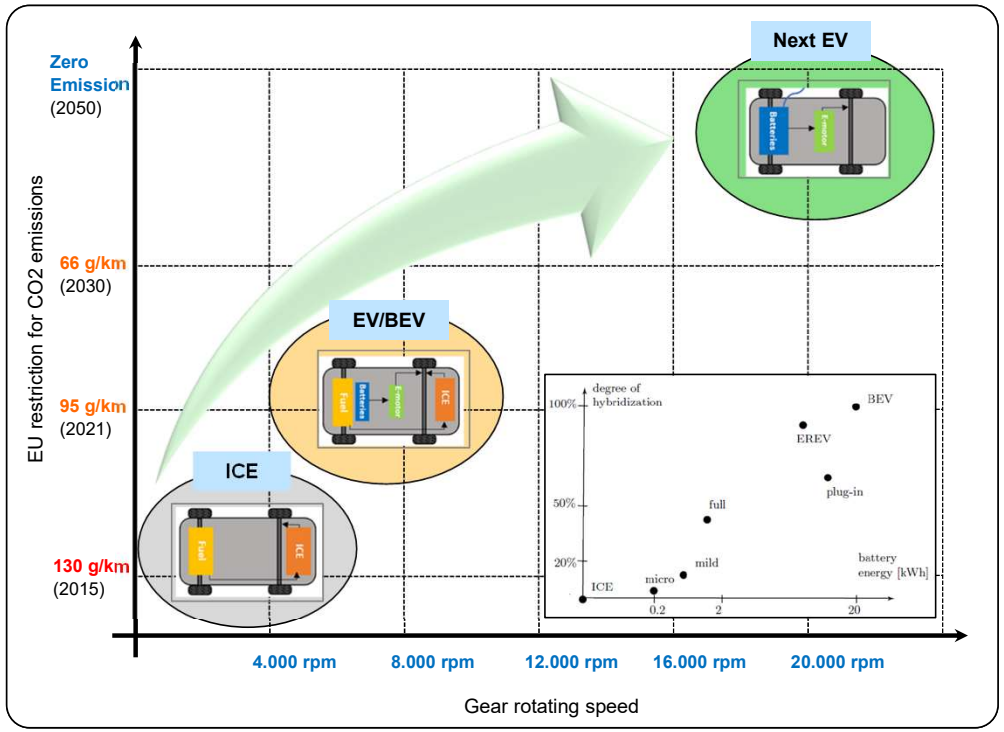


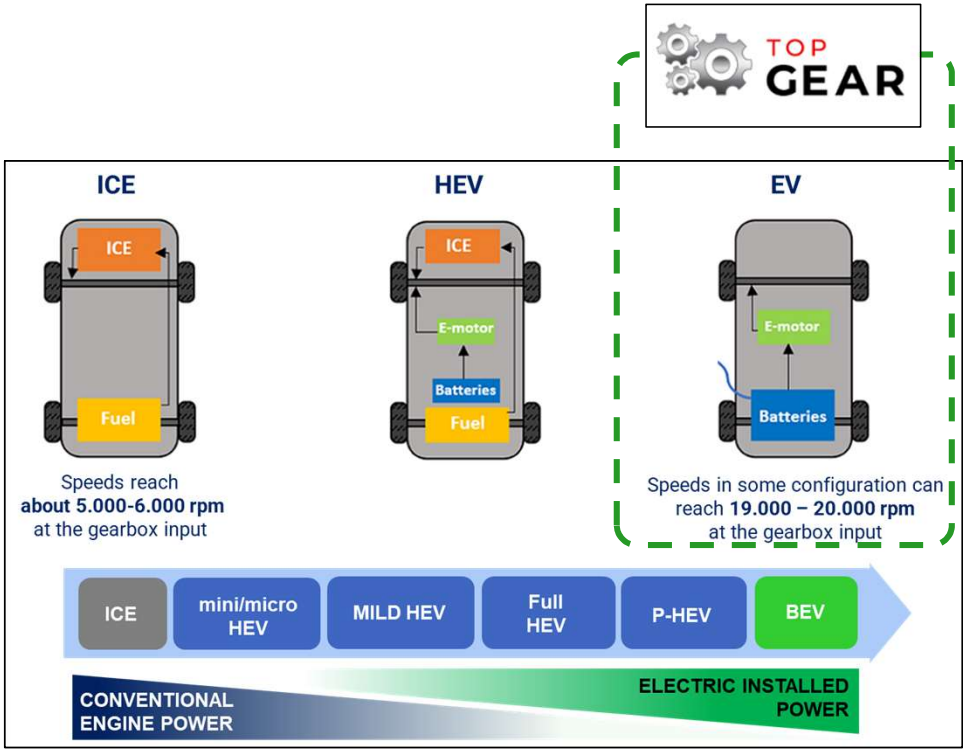
- Produce the peak torque at zero rpm and its shaft can rotate in both directions
- No moving-off element required thanks to high torque capability at low motor speed

ICE Vs EV Gearbox
(Torque-Speed relation)



- **Possibilities of application to BEV gearboxes**

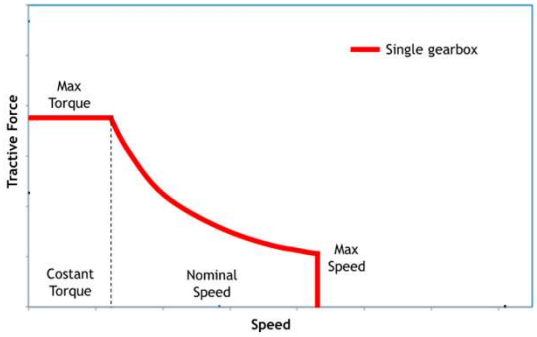




ECONOMIC ANALYSIS AND POSSIBILITIES OF APPLICATION TO BEV GEARBOXES

- **Conclusion**

Single-Speed Transmission

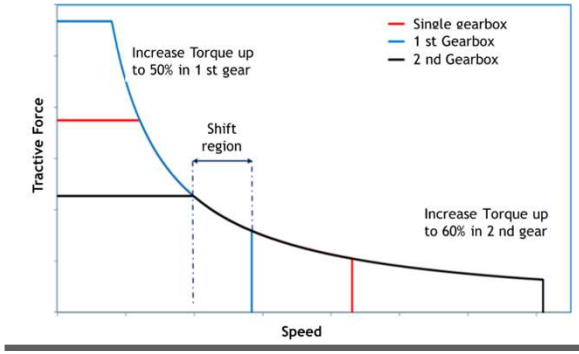


Application
Focus on simplicity and reliability
For Sandard electric vehicles

Advantages
Fixed gear ratio (eg between 8:1 and 12:1)
It generates instant torque
No complex gear system is required
Little space occupied

Limitations
Fixed transmission ratio

Multi-Speed Transmission



Application
Focus is on performance for Sporty or Luxury vehicles

Advantages
Variable ratio (e.g. 15:1 in first gear, 8:1 in second)
The stall torque can be increased
The maximum vehicle speed can be increased

Limitations
Transmissions are too heavy and large
It has a very high cost

TOPGEAR

Application:
- Suitable to satisfy city electric cars with single speed transmission
- Key factors applications: reliability, robustness of construction and low maintenance
- Solution coupled with high efficiency electric motors, capable of operating well at high RPM

Characteristics :
- increase of fatigue and mechanical resistance
- no scuffing damage occurs
- Reduce friction losses at high speeds
- Improve system reliability
- Support high-performance vehicles that require higher gear ratios

Thank you for your attention!

www.topgear-project.eu

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