Transient operating point definition and energy flux analysis using FASI 6.0

Thomas Lugmayr, ECS, Magna Powertrain

Agenda

- Introduction
- Input Parameters
- Adjustment & Results
  - Vehicle Power
  - Vehicle Acceleration
  - Driving Simulation
- Fields of Application
- Outlook

POWERTRAIN

MAGNA POWERTRAIN

What is FASI?

- Split into **three Modules**
  - Vehicle Power (speed, power, grade ability)
  - Vehicle Acceleration (acceleration performance, elasticity)
  - Driving Simulation (fuel consumption and load collective)
- **Comfortable** graphical user interface
  - Postprocessor (similar to KULI)
  - Self explaining dialogs
- **Interface** to KULI and EXCEL
- **Single track** driving simulation tool
- Prepared **drivetrain models**

POWERTRAIN

MAGNA POWERTRAIN

Supported Vehicle Types

Dump and cargo trucks

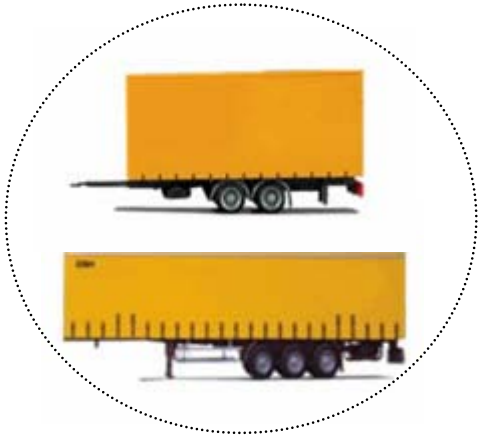
Semi trailer trucks

Tractors

Cars

Bikes

+



90% of the vehicles can be simulated

MAGNA
MAGNA POWERTRAIN

Why using FASI?

- Find out the best vehicle configuration

  Which **gearbox is the best** for my Vehicle?

- Identify fuel saving and emission reduction potentials

  Where is all the **energy going to**?

- Compare component performance

  Which **improvement** is achieved by a new engine?

- Determine engine operating points for KULI

  Operating point at 30km/h and 12% grade?

- Determine **load statistics**

  For which load the rear axle has to be designed?

Typical questions in vehicle development

POWERTRAIN

MAGNA POWERTRAIN

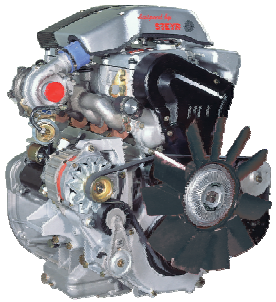
Agenda

- Introduction
- Input Parameters
- Adjustment
  - Vehicle Power
  - Vehicle Acceleration
  - Driving Simulation
- Fields of Application
- Outlook

POWERTRAIN

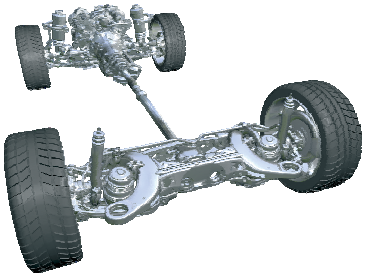
MAGNA POWERTRAIN

FASI Input Parameters



Engine

Gearbox



Axles & Tires

Driver

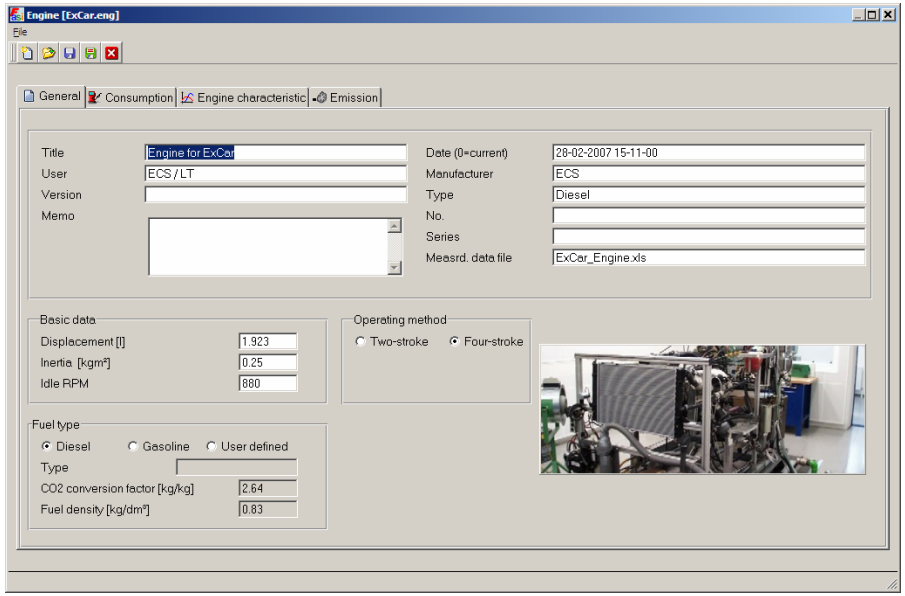
Route

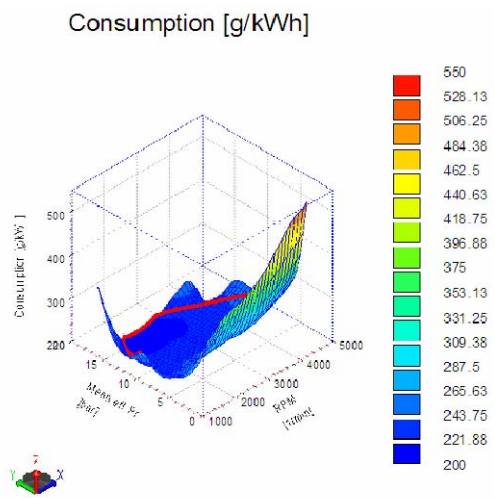
Vehicle

MAGNA
MAGNA POWERTRAIN

POWERTRAIN

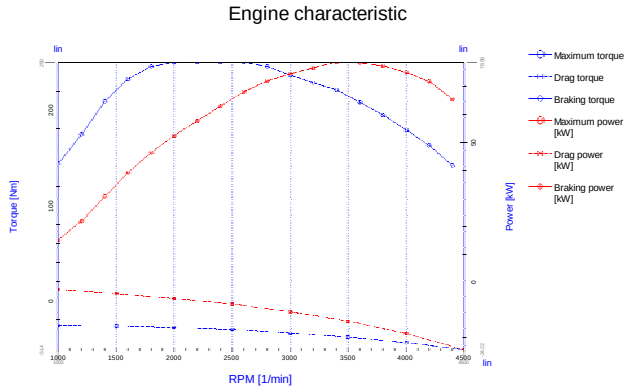
Input Parameters: Engine



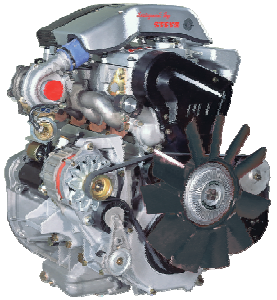


Fuel map

- Engine type
- Displacement
- IDLE speed
- Inertia
- Fuel density
- CO_2 factor



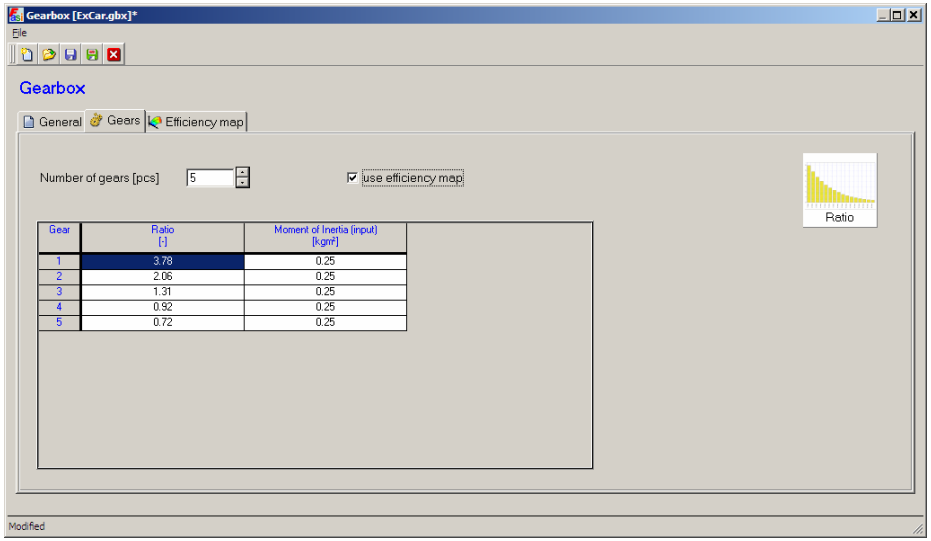
Torque characteristics



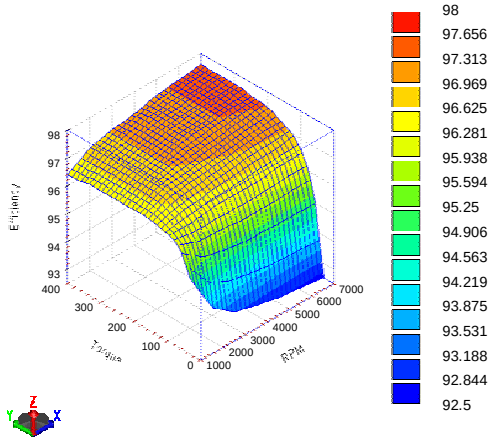
MAGNA POWERTRAIN

POWERTRAIN

Input parameters: Gearbox & Transfer Case

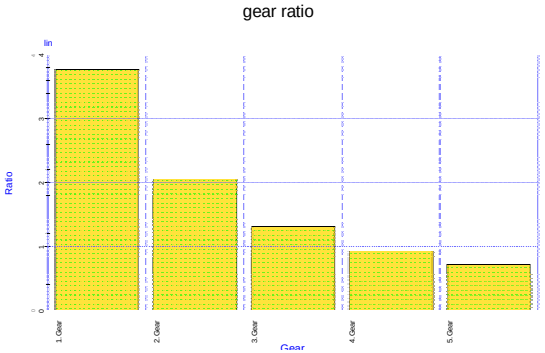


Efficiency map [3]



Efficiency map

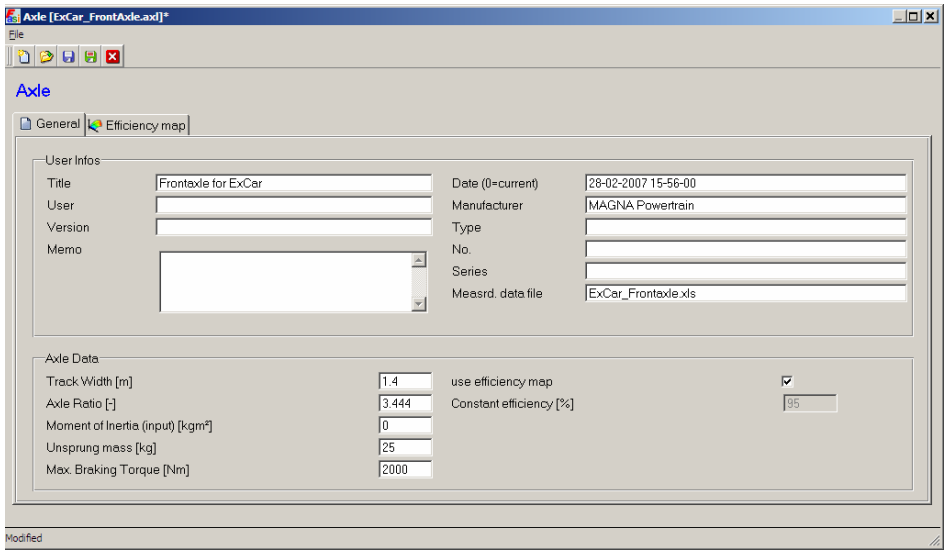
- Moment of inertia
- Number of gears
- Transmission ratio
- Constant efficiency or map



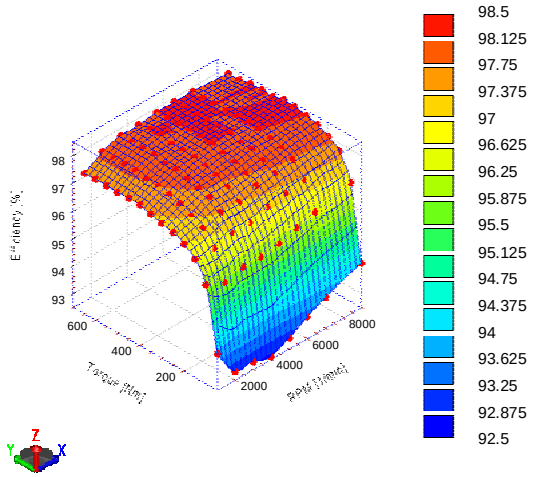
Gearbox ratio & inertia

MAGNA POWERTRAIN

Input Parameters: Axles



Efficiency map

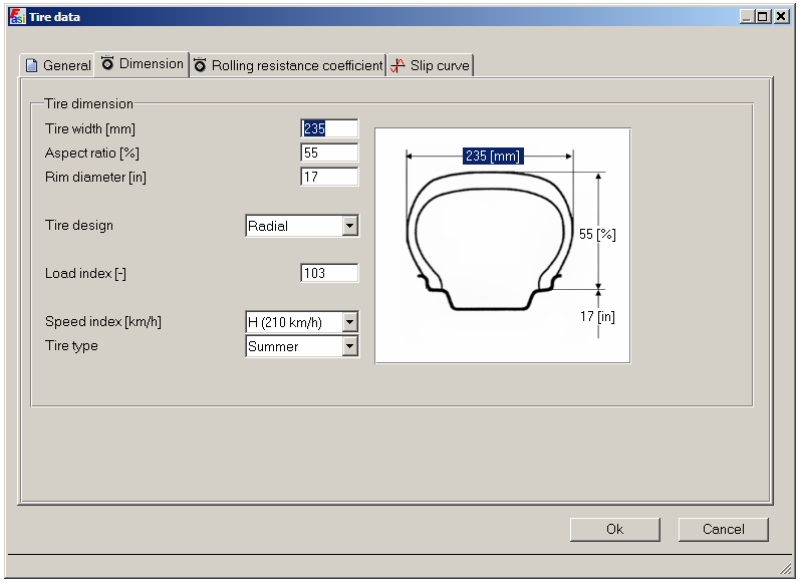


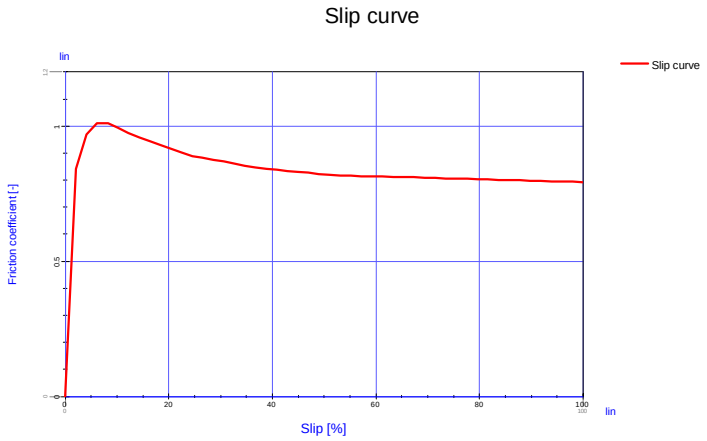
Efficiency map

- Ratio
- Moment of inertia
- Constant efficiency or map
- Maximum brake torque

MAGNA POWERTRAIN

Input Parameters: Tires





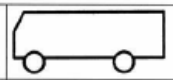
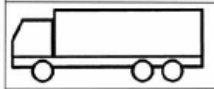
Slip curve

- Tire dimension
- Rolling resistance (as function of velocity)
- Rolling circumfence (as function of velocity)
- Mass
- Inertia
- Static radius

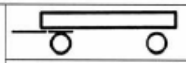
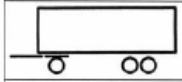
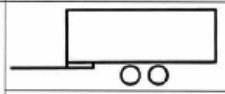
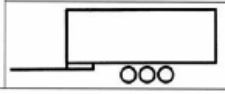
FASI comes with a tire database including common tires

MAGNA POWERTRAIN

Input Parameters: Vehicle

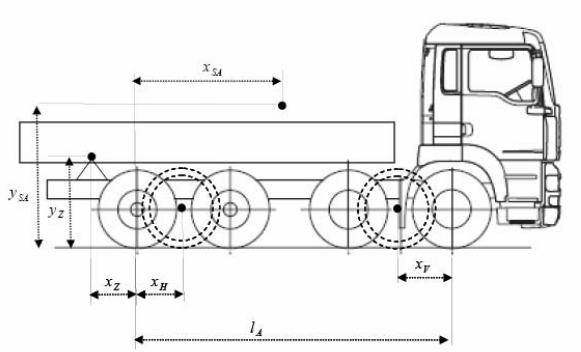
Kastenwagen		
Lastkraftwagen		4 × 2, 4 × 4
		6 × 2, 6 × 4, 6 × 6, 6 × 2/4, 6 × 4/4
		8 × 4/4, 8 × 6/4, 8 × 8/4

Vehicle types

Gelenkdeichsel-anhänger		Plattformanhänger
		Plateau-Tiefladeanhänger
		Tiefladeanhänger mit einfacher Kröpfung (Bild 3-7)
		Tiefbett-Tiefladeanhänger
Zentralachs-anhänger		Zentralachs-Plattformanhänger
		Zentralachs-Tiefbettanhänger

Trailer types

- # of Axles and Tires per axle
- Axle load
- CoG Height
- Wheelbase
- Air resistance coefficients
- 4x2; 4x4 etc.
- Trailer



MAGNA POWERTRAIN

Agenda

- Introduction
- Input Parameters
- Adjustment & Results
  - Vehicle Power
  - Vehicle Acceleration
  - Driving Simulation
- Fields of Application
- Outlook

POWERTRAIN

MAGNA POWERTRAIN

Steps of Adjustment

- Vehicle Power
  - Stationary analysis without inertia

- Vehicle Acceleration

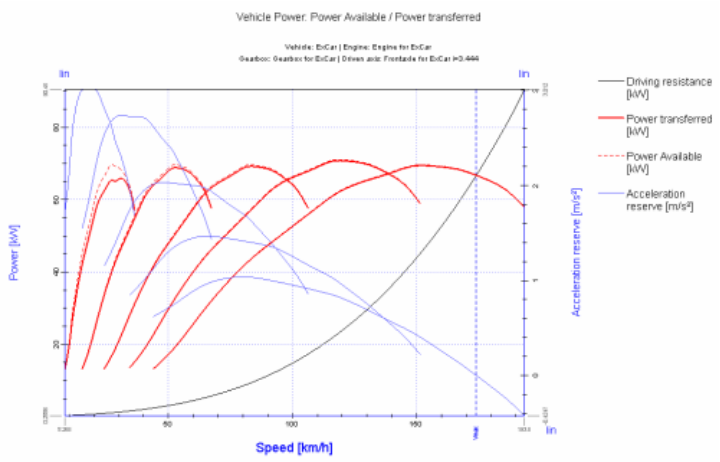
- Driving Simulation

MAGNA
MAGNA POWERTRAIN

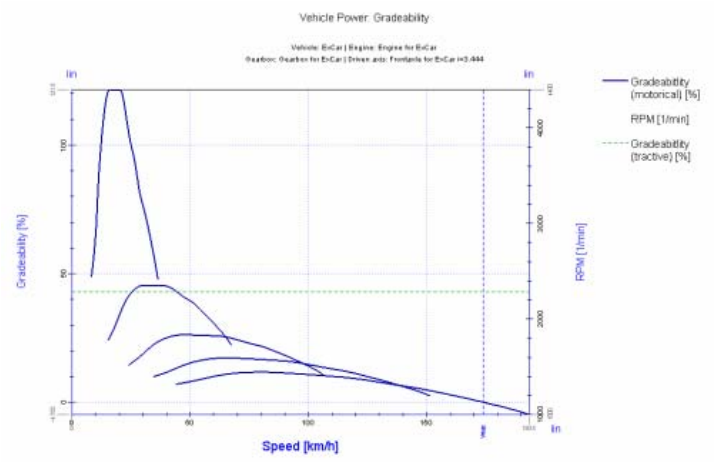
POWERTRAIN

Vehicle Power

- **Maximum speed**
- Peak power speed
- **Gradeability** (engine power / tractive)
- **Friction coefficient** at full load
- Full load **slip**
- **Power** wheel and transferred to road surface
- Influence of a **trailer** to these data



Available and transferred power

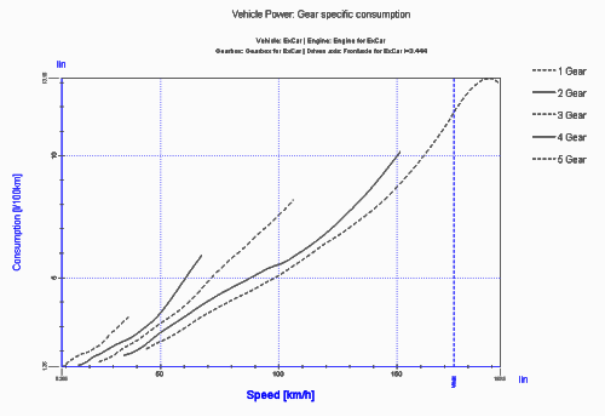


Gradeability

MAGNA POWERTRAIN

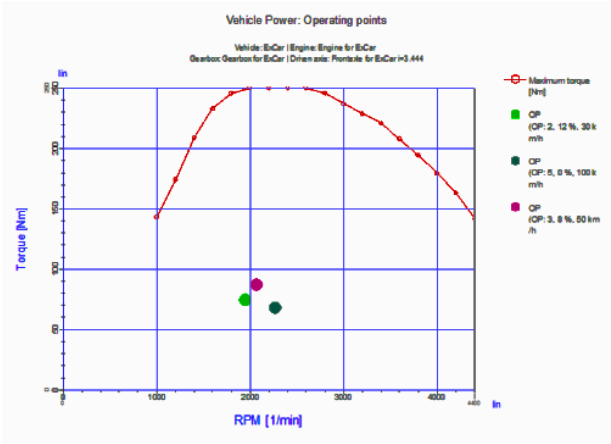
Vehicle Power

- **Consumption** per gear (absolute and relative)

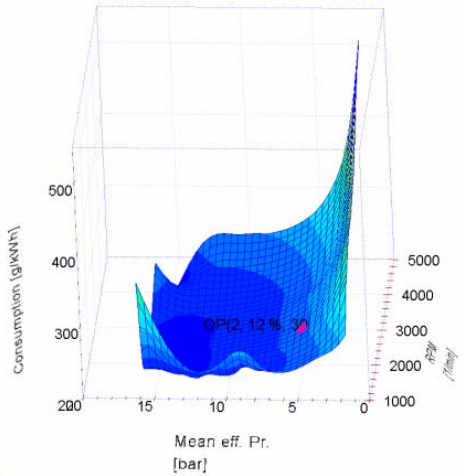


Consumption per gear

- Specific **operating point** determination



Operating points



Steps of Adjustment

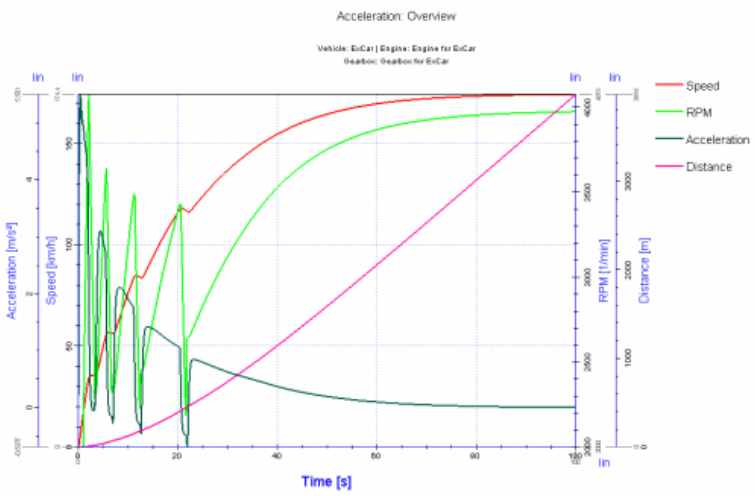
- Vehicle Power
  - Stationary analysis without inertia
  - Adjustment of maximum speed (slip, tire radius, air resistance)
  - Verification of gradeability
- Vehicle Acceleration
  - Transient analysis
- Driving Simulation

MAGNA
MAGNA POWERTRAIN

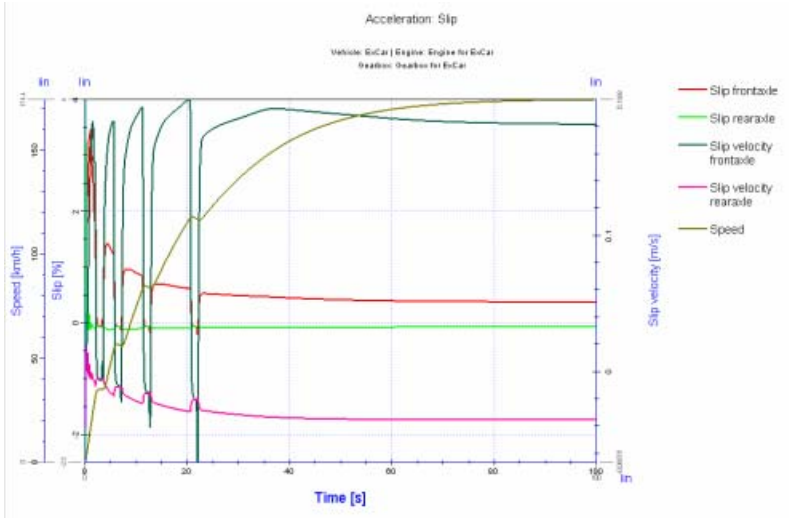
POWERTRAIN

Vehicle Acceleration

- **Acceleration** times to a **defined speed** (e.g. from zero to 100 km/h)
- **Elasticity** in a certain gear from one to another velocity
  (e.g. from 80 to 120 km/h at 5th gear).
- **Slip** and sliding velocity during the simulation
- **Speed** after a certain **distance** (e.g. after 1000 m)
- Free definable shifting sequence



Acceleration times



Slip and sliding velocity

Steps of adjustment

- Vehicle Power
  - Stationary analysis without inertia
  - Adjustment of maximum speed (slip, tire radius, air resistance)
  - Verification of gradeability

- Vehicle Acceleration
  - Transient analysis
  - Adjustment of elasticity (inertia)
  - Adjustment of acceleration times (drivers pedal)

- Driving Simulation
  - Fuel consumption like measurement?

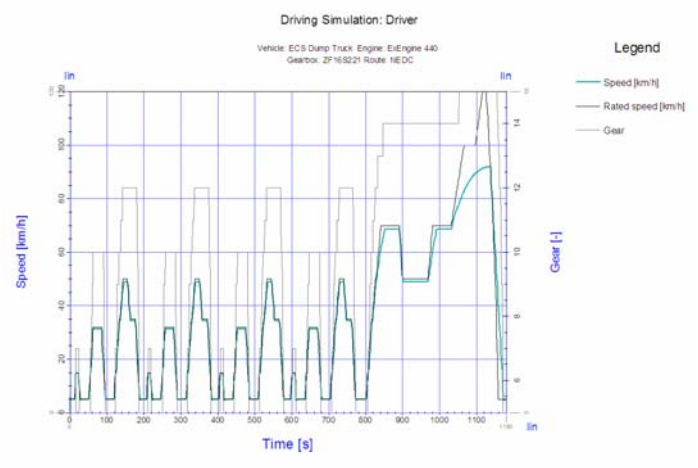
Robust simulation model

MAGNA
MAGNA POWERTRAIN

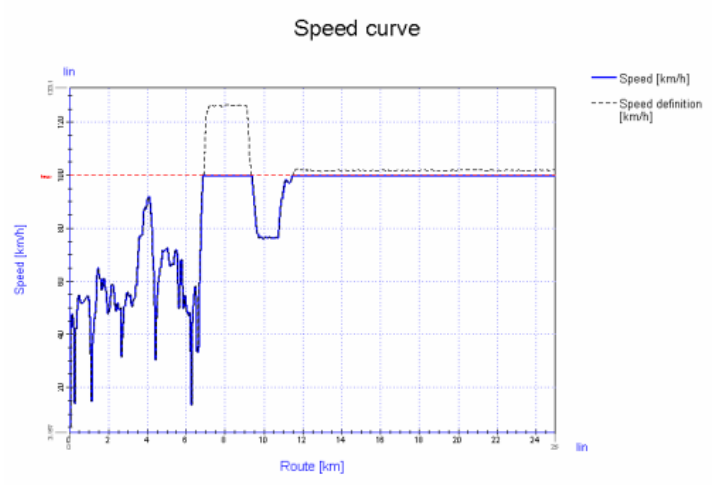
POWERTRAIN

Input Parameters for Driving Simulation: Route

- Definition via **time or distance**



Time based NEDC



Filter

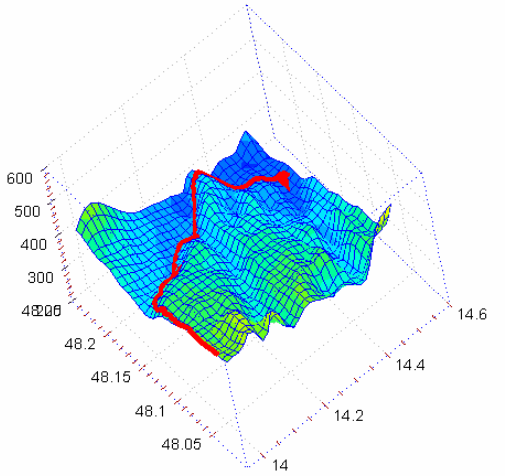
- **Velocity Preprocessor** depending on:
  - Curvature
  - Braking performance
  - Allowed speed

Input Parameters for Driving Simulation: GPS Import

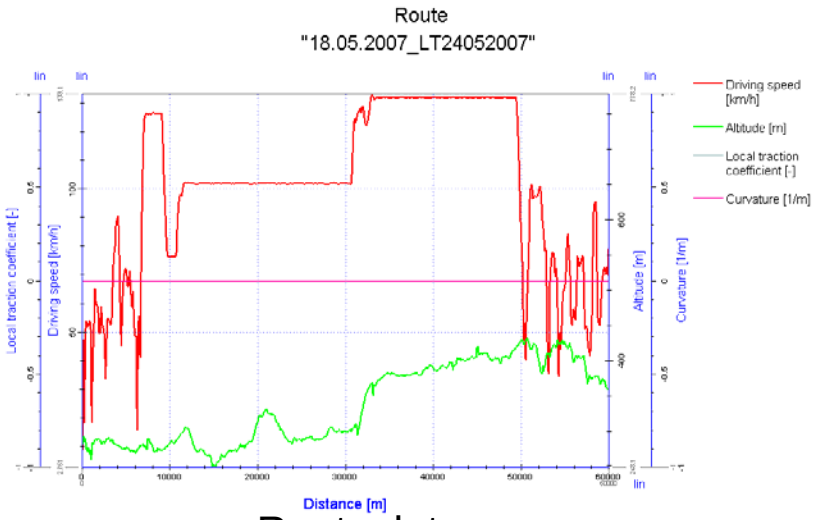

```
$GPGGA,051130.935,4802.4999,N,01359.2090,E,1,03,33.7,463.1,M,45.7,M,0.0,0000*4F
$GPGLL,4802.4999,N,01359.2090,E,051130.935,A*3B
$GPRMC,051130.935,A,4802.4999,N,01359.2090,E,0.000000,,140704,,*14
$GPVTG,,T,,M,0.000000,N,0.000000,K*4E
```

GPS Receiver

- Velocity characteristic (optional)
- Height profile
- Curvature (optional)



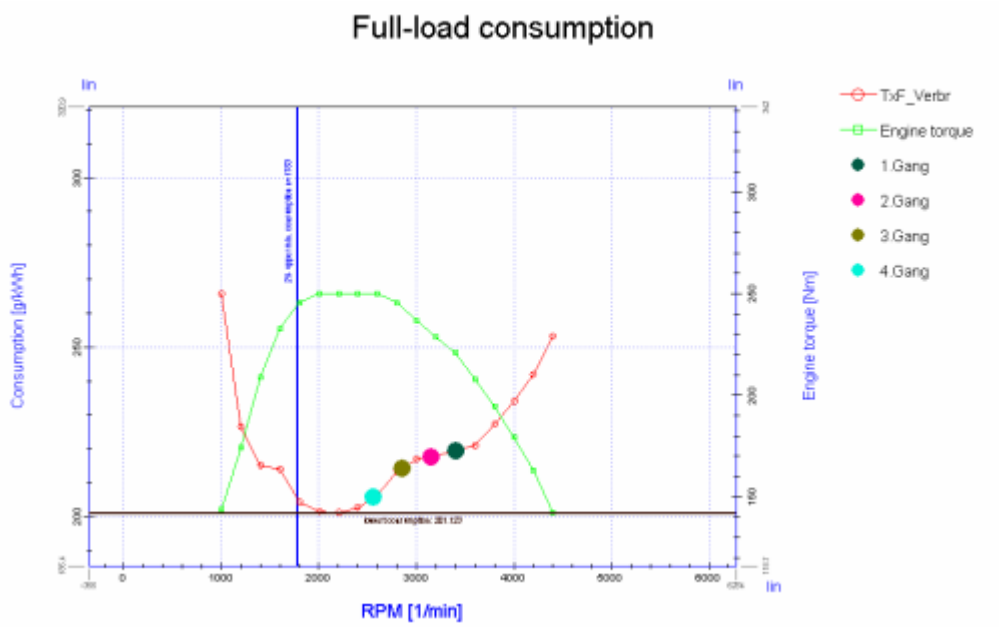
Import Filter



Route data

Input Parameters for Driving Simulation: Driver

- **Fast or consumption optimized** driving style
- Calculation of **shift RPM** based on fuel map
- Free parameterizeable **controller**
- Maximum throttle position
- Costs



Gear	Upshift RPM [1/min]	Downshift RPM [1/min]
1	3400	
2	3145	2100
3	2848	2100
4	2556	2100
5		2100

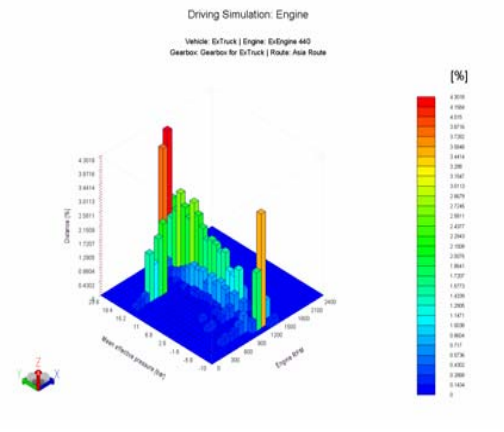
Shift RPM

Driving Simulation

- **Fuel consumption** along a certain route
- **Load collective** (e.g. gearbox, engine, and all other components of the drivetrain)
- **Statistic** evaluation (e.g. load, rpm of each component)
- Engine **operating characteristic**
- Total costs
- Driving time
- **Driveability**
- **CO_2** emission

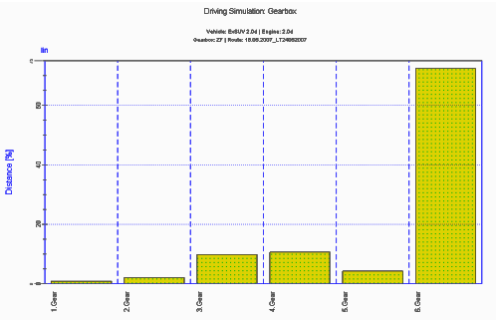
```
Vehicle name:                    ExSUV 2.0d
Route name:                      18.05.2007_LT24052007
Date / Time:                     31-05-2007 13-49-45
Calculation duration:            51.42     [s]
Errors:
Messages:

Results:
-------------------------------------------------------------------

Driving time:                    284.79    [min]
Distance travelled:              348.509   [km]
Average velocity:                73.42     [km/h]
Total fuel consumption:          27.68     [l]
Average fuel consumption:        7.94      [l/100km]
Mileage:                         12.59     [km/l]
Number of gear shifts:           464       [-]
Total CO2-Emission:              73.07     [kg]
CO2-Emission:                    209.67    [g/km]

Costs:
-------------------------------------------------------------------

Fuel costs:                      27.13     [EUR]
Operation costs:                 131.04    [EUR]
Operator costs:                  379.72    [EUR]
Total costs                      537.88    [EUR]
```

Context



Load collective

Driving resistances



Gearbox statistic

MAGNA POWERTRAIN

Agenda

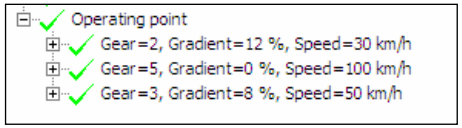
- Introduction
- Input Parameters
- Adjustment & Results
  - Vehicle Power
  - Vehicle Acceleration
  - Driving Simulation
- Fields of Application
- Outlook

POWERTRAIN

MAGNA POWERTRAIN

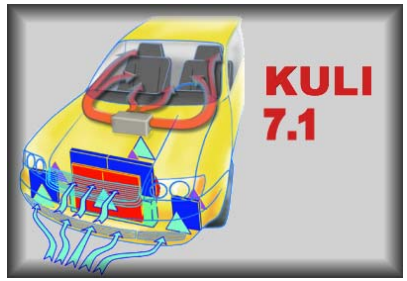
Determination of Stationary KULI Input Data

Target:
Determine KULI operating point
by **Velocity, Gradient** and **Gear**



Adjusted model

FASI calculates:
Mean effective pressure
Engine **RPM**

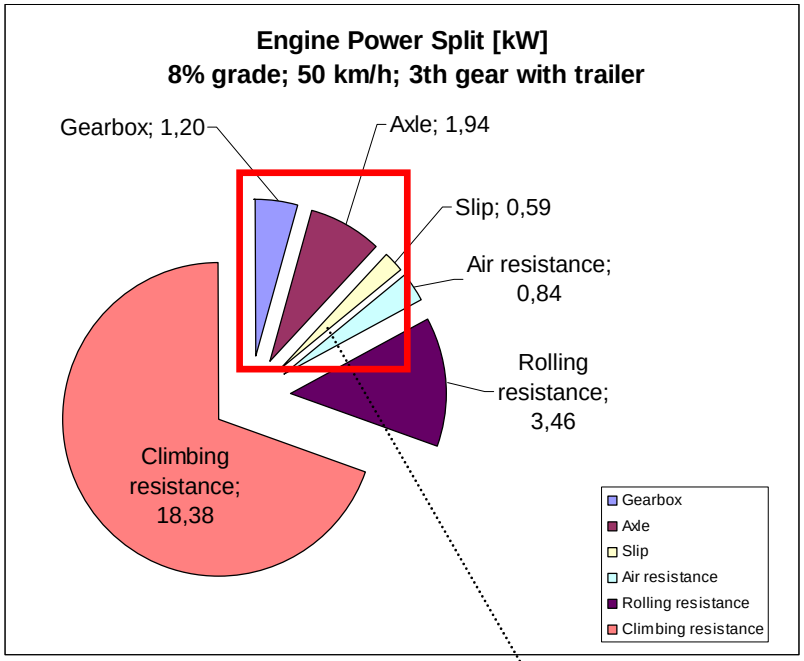


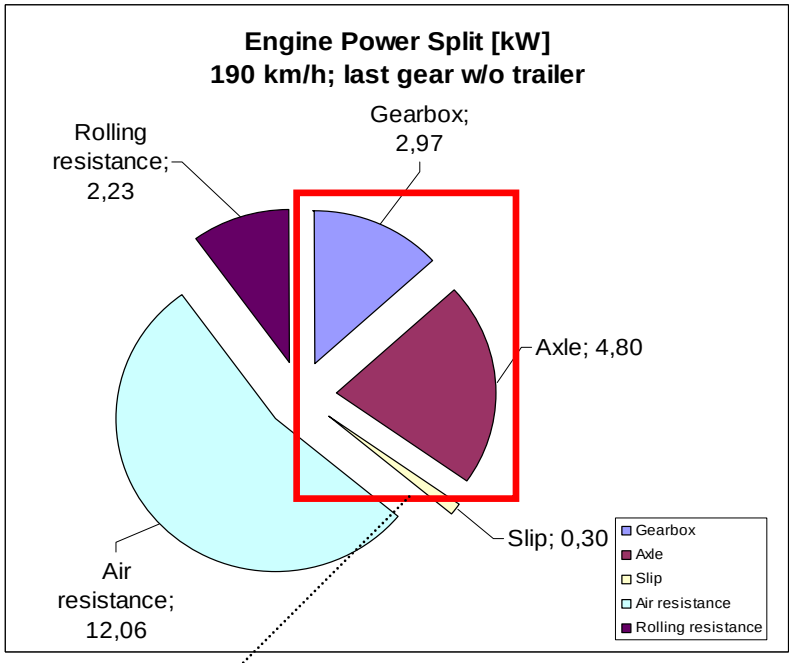
KULI

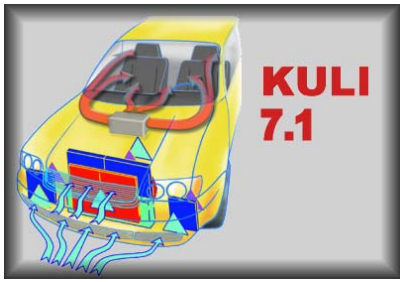
MAGNA
MAGNA POWERTRAIN

POWERTRAIN

Determination of Stationary KULI Input Data







KULI Input:
Power loss at
gearbox and **axles**

Determination of Transient KULI Input Data

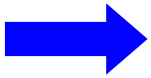
Route

Adjusted model

Driver

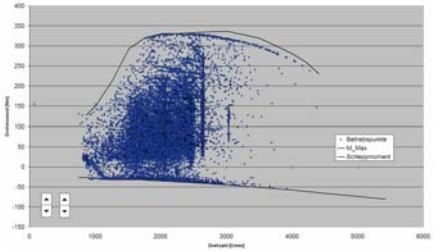
FASI calculates:

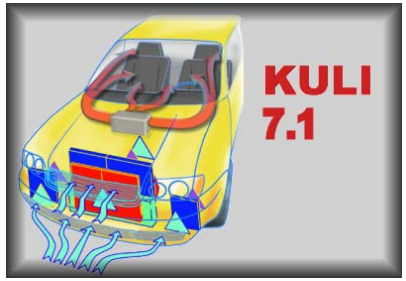
Engine **operating points**
(velocity, RPM and mean effective pressure).



Power loss of efficiency map
in gearboxes and axles.

Ambient conditions depending
on route profile (ISA).





KULI

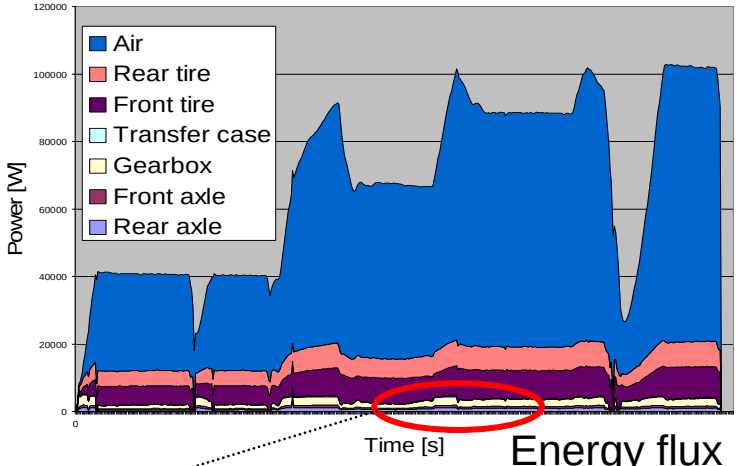
MAGNA
MAGNA POWERTRAIN

POWERTRAIN

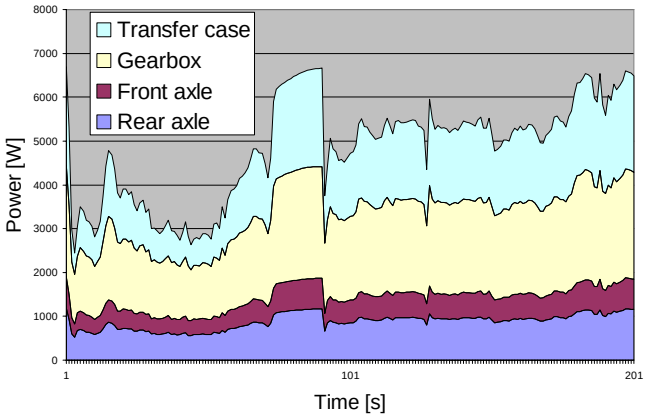
Determination of Transient KULI Input Data

Route profile

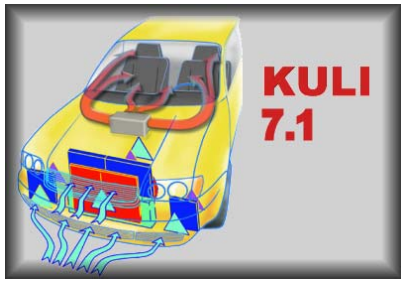
Detailed energy flux breakdown



Energy flux

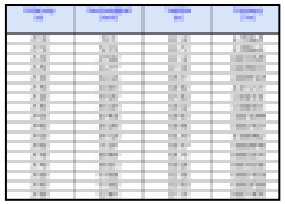


Energy flux (zoom)



KULI

Measurement Data Enhancement

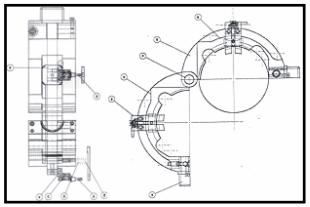


Measurement

I/O Information, single values

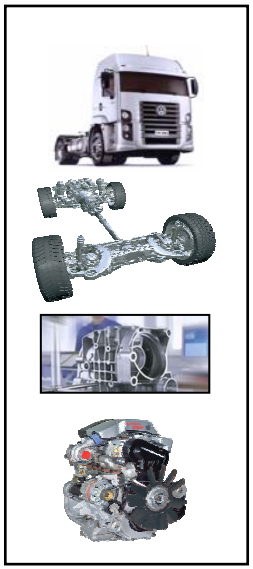
?

Adjustment, plausibility check

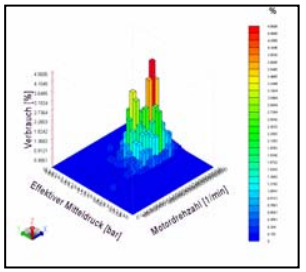


Design

Measurement valid?



Components

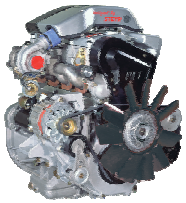


Load collective for all components

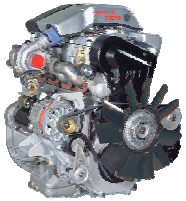
MAGNA
MAGNA POWERTRAIN

POWERTRAIN

Component Comparison

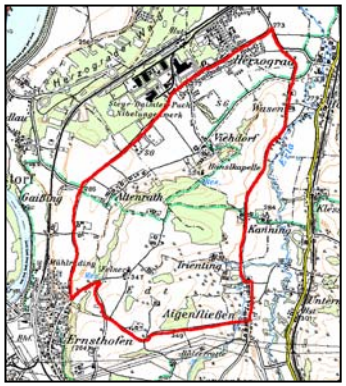


Engine a



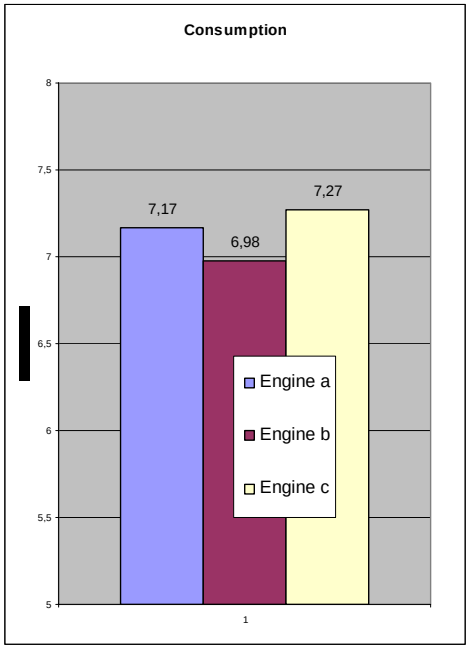
Engine b

Engine c



Route

Adjusted model



Fuel Consumption

MAGNA
MAGNA POWERTRAIN

POWERTRAIN

Agenda

- Introduction
- Input Parameters
- Adjustment & Results
  - Vehicle Power
  - Vehicle Acceleration
  - Driving Simulation
- Fields of Application
- Outlook

POWERTRAIN

MAGNA POWERTRAIN

Outlook

- Full integration of FASI in KULI in Version 8.0

  Powertrain components as heat sources in KULI

  Engine performance depending on **temperature** (Friction power, Turbocharger, …)

  Gearbox model in KULI

- Increased number of **supported powertrain types** like

  Hybrid technology

  Hydrostatic powertrain

POWERTRAIN

MAGNA POWERTRAIN

Thank you for your attention!

FASI Workshop, Friday 11am

POWERTRAIN

MAGNA POWERTRAIN