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MECA0525 PERFORMANCE AND DYNAMICS OF VEHICLES

PERFORMANCE ASSESSMENT

HOMEWORK 1

The first homework you are asked to carry out is to study and simulate the performance of an internal combustion engine vehicle. This year we are going to consider the ***FORD Puma 1.0 Ecoboost (model 2020)***

Figure 1 : Ford PUMA

The car manufacturer web site[1] and the dedicated press[2] announce the following data:

ENGINE

- Pmax = 70 kW @4000-6000 rpm (take N1=5000 rpm)
- Cmax = 170 Nm @1400 à 3900 rpm (take N2=2000 rpm)

TRANSMISSION

- Transmission to the front wheels
- Fixed gear ratio (differential): 4.35 :1
- Gear ratio of the gear box and transmission length: see table
- Transmission efficiency η: to be estimated by you if it is known that the engine is mounted transversally in front.

[1] https://media.ford.com/content/fordmedia/feu/en/products/suv/puma/puma.html
[2] https://www.automobile-catalog.com/auta_perf1.php

Gear	Ration	Total gear ratio	Speed@1000 rpm
1	3.417 :1	14.86 :1	8.5 km/h
2	1.958 :1	8.520 :1	14.9 km/h
3	1.276 :1	5.550 :1	22.9 km/h
4	0.943 :1	4.100 :1	30.9 km/h
5	0.757 :1	3.290 :1	38.5 km/h
6	0.634 :1	2.760 :1	46.0 km/h
R	3,833 :1		

VEHICLE

- Length/Width/Height (mm): 4186/1805/1550 mm
- Wheelbase (mm): 2588 mm
- Curb weight: 1194 kg (without the driver estimated to 75 kg)
- Tires: 205/65 R16 H (serial mount)
- Effective rolling radius R_e: to be estimate using information available in the lecture or data available on the net (better!)
- Tire rolling resistance: f = 0.0136 + 0.4*10-7 V^2 (with V in km/h)
- Air density ρ=1,22 kg/m³
- C_X = 0.32 S= 2,32 m² S Cx = 0,743 m²
- Fuel (gasoline) density: ρ=0,755 kg/l @ 15°C

POSITION OF THE CENTER OF MASS

- Weight distribution between front and rear axles: 50/50
- The elevation of the center of gravity as given by h= 0,20 L

EXPECTED OUTCOMES

Part 1: Performance assessment

We ask to:

1. Estimate the missing parameters.
2. Plot the curves of the resistance forces between 0 and 60 m/s for three slopes: 0, 3 and 10%.
3. Compute the approximation of performance curves of the engine (torque and power) using the strategies shown in the lecture (power, polynomial fits of order 3 and 4). Compare the 3 approximations.
4. Plot the tractive forces at wheels and the road resistance forces against the vehicle speed. Plot the tractive power and resistance power against the vehicle speed. Discuss.
5. Plot the net tractive force and net power curve and the acceleration capability of the vehicle (me/Fnet) as a function the speed for the different gear ratios.
6. Compute the maximum max speed of the vehicle, the related transmission length and its gear ratio if we keep the same differential and the same wheel diameters. Compare with the actual gear ratio implemented in the car.
7. Compute the actual maximum speed on the last gear ratio.
8. Compute the maximum slope on the first gear ratio (assume negligible speed).
9. Compute the maximum slope at 100 km/h on the 5th gear ratio.
10. Compute the acceleration time from 90-120 km/h on the 5th gear ratio.

11. Compute the acceleration time to cover 400 m from 40 km/h on the 5th gear ratio.
12. Compute the 40-120 km/h starting from the 3rd gear ratio while changing the gear ratios. The gear changes are selected to optimize the acceleration time. Discuss your strategy of gear change.

Part 2 : Fuel consumption

1. Plot and discuss the specific fuel consumption on the engine map. Superimpose engine characteristics and specific fuel consumption. Plot resistance curves seen by the engine for the different gear ratios.
2. Compute the fuel consumption (l/100 km) at constant speed in the following conditions and select the gear ratio to minimize the fuel consumption:
    a. 20 km/h
    b. 30 km/h
    c. 50 km/h
    d. 70 km/h
    e. 90 km/h
    f. 120 km/h
3. Compute the fuel consumption (l/100 km) at constant speed for each gear ratio as a function of the speed. Plot the different curves against the vehicle speed. The fuel consumption curves in the vehicle diagrams may resemble U-shaped curves as the engine speed changes from idle to maximum speed.
4. Calculate the fuel consumption over the variable speed driving cycle shown in Figure 2.
5. To study the effect of driving aggressiveness on fuel consumption, consider the cycles in Figure 3. Compare the increase in fuel consumption if the maximum plateau speed varies between 15 m/s, 20 m/s, 25 m/s, and 30 m/s.
6. Estimate the fuel consumption when the temperature drops at -5°C requiring heating up the cabin and using deicing or when outdoor temperature is 35°C and that air conditioning has to be used. Review the literature to estimate the extra energy consumption for hotel climate control.
7. What is your conclusion about reducing the speed limits from 50 km/h to 30 km/h in city centers. Please consider multiple aspects in elaborating your discussion (not only fuel consumption)?
8. Compute the fuel consumption against the European Driving Cycle (NEDC)
    a. What is the consumption for the urban driving cycle only?
    b. What is the consumption for the extra urban driving cycle?

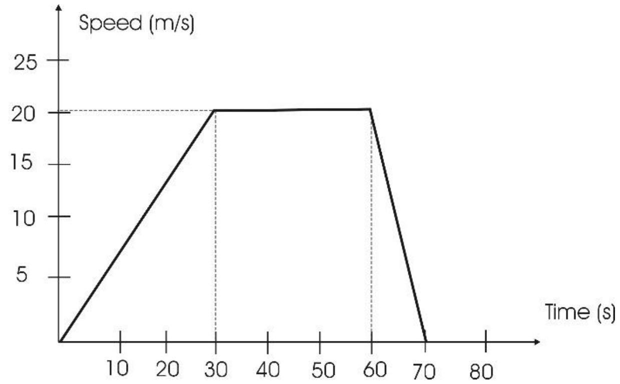

Figure 2: Driving cycle 1

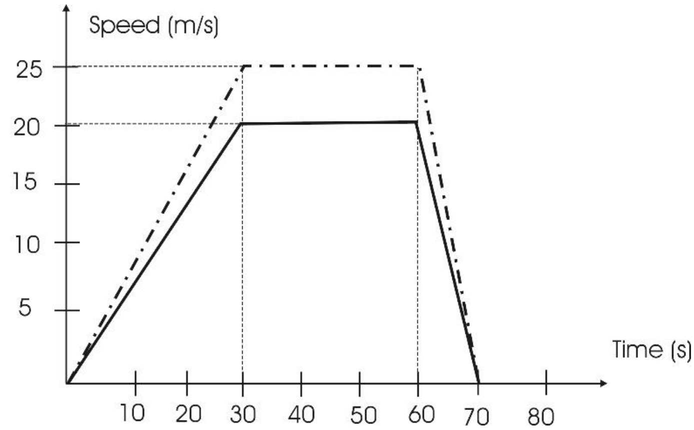

Figure 3: Driving cycle 2

Terms of Duty:

The work will be done in groups of two students.

Each group will submit a single report of a maximum of 30 pages. The report will include a description of the hypotheses made, the equations used, the complete results (possibly in appendix), a critical analysis of the results, a copy of the calculation codes used (possibly in appendix).

The report will be submitted by email to p.duysinx@uliege.be by Sunday, April 3, 2022 at 23:59 (Brussels time).

ANNEX 1 : Engine characteristic curves

The web site[3] www.automobile-catalog.com provides the following engine curves:

[3] https://www.automobile-catalog.com/curve/2020/2919065/ford_puma_1_0_ecoboost_95.html

ANNEX 2 : Fuel consumption map

The fuel consumption map is given using the Golverk approximation (SAE 941928).

$$bsfc = A_1 + A_2\, N + A3\, T + A_4\, N^2 + A_5\, N.T + A_6\, T^2$$

- bsfc [gr/kWh] the brake specific fuel consumption
- T [Nm], the engine torque
- N [rpm], the engine rotation speed
- Ai: empirical coefficients fitted to experiments

Coef.	**1.0 L**	**1.5 L**
A1	340	376
A2	-0.026200	-0.026300
A3	-0.880000	-0.963000
A4	0.00001	0.00001
A5	-0.000100	-0.000115
A6	0.002400	0.002670