TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11, 98–105

ANALYSIS OF TRACTION CHARACTERISTICS OF THE MOTOR CAR FIAT PANDA EQUIPPED WITH A 1.3 16 V MULTIJET ENGINE

Wawrzyniec Gołębiewski*, Tomasz Stoeck *

* Department of Motor Vehicle Use, the West-Pomeranian University of Technology in Szczecin

Summary. This paper presents analysis of traction characteristics of the Fiat Panda car equipped with a 1.3 16 V Multijet engine. Characteristics of the full power of the 1.3 JTD engine was prepared, along with a selection of the trend curves. On the basis of the moment curve from that graph and the car basic data, traction characteristics of the vehicle was prepared. It was a dependence of the propulsive force on the vehicle's linear velocity. On that basis, such traction qualities of the Fiat Panda as its ability to accelerate, to drive upon hills and its achieving the maximum speed were analyzed.

Key words: traction characteristics of a vehicle, theory of motion, combustion engines, external characteristic of an engine.

INTRODUCTION

Acceleration potential is one of the most important traction characteristics of a vehicle. It finds its reflection in urban traffic. A higher number of cars that manage to drive over a crossing in one light cycle results in a lower number of cars waiting before the crossing, which translates to a lower emission of combustion gases from engines working idle.

Moreover, quick passing is also important, as it shortens the time of the hazardous maneuver. This quality of the car is strongly affected by the external characteristics of the engine torque and selection of an appropriate power transmission system.

Overcoming heights by the vehicle at its maximum speed is meaningful, too.

These traction qualities describe the essence of the vehicle work and the character of its use.

PURPOSE OF THE RESEARCH

Purpose of this research was to perform analysis of traction characteristics of a motor vehicle Fiat Panda, equipped with a 1.3 16 V Multijet engine.

TESTING STATION

The testing station was composed of the following components:

- a fuel (diesel oil) tank – a 200 l fuel tank for diesel oil,
- a fuel pump – it was supposed to ensure fuel pressure from the tank and its delivery to the fuel pipes,

"Automex" fuel meter – it was an important component, necessary for measuring fuel consumption with the weighing method (not included in the scope of the tests). Unburnt fuel returned to it through the engine,

- a Fiat Multijet 1,3 JTD engine – a four-stroke turbo-charged diesel engine with direct injection, provided with the Common Rail fuel delivery system,
- an „Automex" eddy current brake – which charged the engine with any chosen anti-torque at variable rotational speeds, using the rotary current phenomenon,
- a power panel with a Fiat Panda 2 switchboard with software and the fuel meter controlling system – controlling the engine work and torque loading the engine via the brake, with a display of the basic operational parameters, including: power, engine torque, etc..

Below, Figure 1 presents the testing station arrangement.

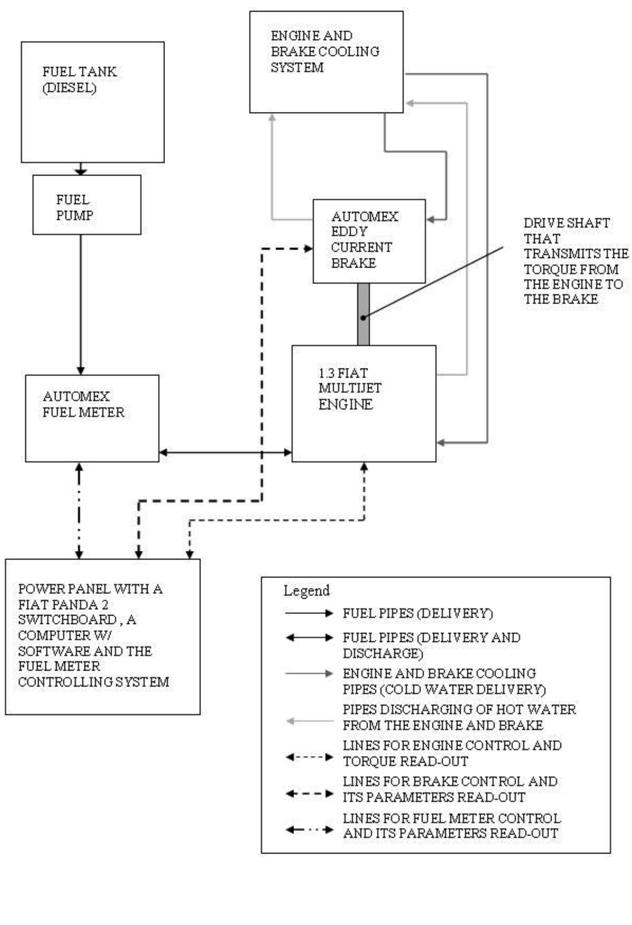

Fig. 1. Arrangement of the testing station (plan)

COURSE OF THE TESTS

During the tests, measurements on a test engine bed were conducted, by performing the engine full power speed characteristic [6,9,16] for the Fiat Multijet 1,3 JTD. It appeared as follows.

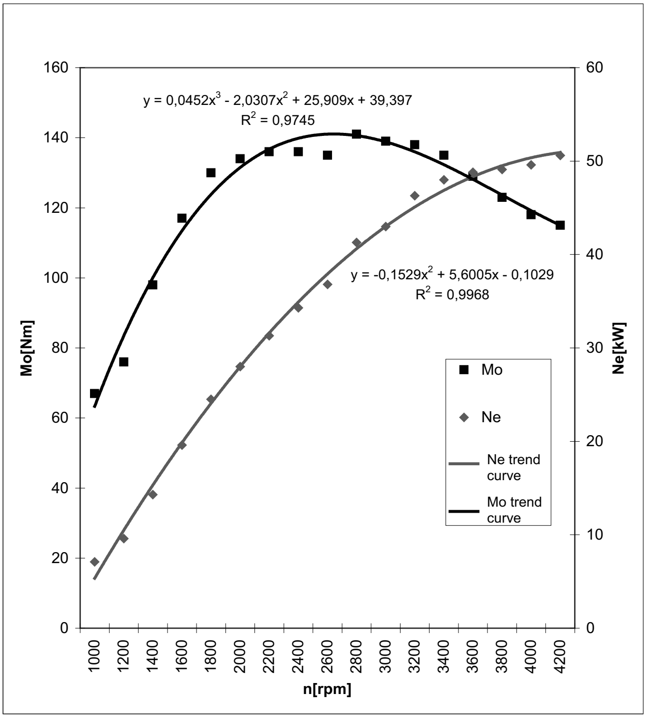

Fig. 2. Speed characteristic of a Fiat Multijet 1,3 JTD engine; Mo – engine torque, Ne – engine power output, n – engine rotational speed, R^2 – correlation coefficient

The measurements were made every 200 rpm, from 1000 rpm to 4200 rpm and the opposite. The result was the mean of the two measurements. For these values, trend curves were matched. Equations characterizing those curves are shown on the graph, where x=1,2,3,... 17 –the next measurement number. High values of the correlation coefficients (R^2) proved the good matching of the trend curves and the actual values. In the table below, results of actual measurements with theoretic values obtained from equations of the matched trend curves are presented.

Table 1. Actual values and theoretical values of the engine torque and power output

	n (rpm)	M_o[Nm]	$M_{o\ theor}$[Nm]	N_e[kW]	$N_{e\ theor}$[kW]
1	1000	67	63.32	7.1	5.34
2	1200	76	83.45	9.6	10.49
3	1400	98	100.07	14.3	15.32
4	1600	117	113.43	19.6	19.85
5	1800	130	123.82	24.5	24.08
6	2000	134	131.51	28	28.00
7	2200	136	136.76	31.3	31.61
8	2400	136	139.85	34.3	34.92
9	2600	135	141.04	36.8	37.92
10	2800	141	140.62	41.3	40.61
11	3000	139	138.84	43	43.00
12	3200	138	135.99	46.3	45.09
13	3400	135	132.33	48	46.86
14	3600	129	128.13	48.8	48.34
15	3800	123	123.67	49.1	49.50
16	4000	118	119.22	49.6	50.36
17	4200	115	115.05	50.6	50.92

where: M_o – actual engine torque, $M_{o\ theor}$ – theoretical engine torque, N_e – actual engine power output, $N_{e\ theor}$ – theoretical engine power output

The next stage of the test was selection of parameters characterizing the vehicle and preparation of a traction graph based on the above-given theoretical characteristic of the engine torque.

VEHICLE DATA

The basic parameters that describe the vehicle include the ones given in Table 2.

Table 2. Basic data of the vehicle

Symbol	Value	Unit	where:
G_c	19325.70	[N]	vehicle weight
f_t^0	0.012	-	basic rolling resistance coefficient
A	0.00005	-	additional rolling resistance coefficient
c_x	0.3	-	non-dimensional air resistance coefficient
k	0.9	-	filling factor
B	1.578	[m]	vehicle width
H	1.54	[m]	vehicle height
F	2.19	[m^2]	vehicle end face area
η	0.9	-	propulsive system mechanical efficiency
σ	1	-	under-hood power loss factor
r_k	0.27	[m]	wheel kinematic radius

Basic assumptions for selecting values for the vehicle data:

- it was assumed that the vehicle is fully loaded, hence its weight (G_c),

- the value of the basic rolling resistance coefficient f_t^0 was adopted as for a surface similar to smooth asphalt,
- the value of the additional rolling resistance coefficient *A* was adopted as for most of surfaces in use,
- the value of the non-dimensional air resistance coefficient c_x was adopted as for a Fiat Panda car,
- the value of the filling factor *k* was adopted as for motor cars,
- the values of the width and height of the car were adopted as for a Fiat Panda, version 4x2 Van,
- the vehicle end face area was calculated based on the dependence $F=kBH$,
- the value of the propulsive system mechanical efficiency was adopted as for motor cars,
- the value of the under-hood power loss factor was adopted as for a vehicle going at elevation of 0 meters above the sea level,
- the wheel kinematic radius resulted from the tire size (at pressure recommended by the producer) and the ring, with consideration of static loads.

Table 3. Basic ratios of gearbox C514R and the final drive [18]

I gear	3.909
II gear	2.158
III gear	1.345
IV gear	0.974
V gear	0.766
Reverse gear	3.818
Final drive	3.438

TRACTION CHARATERISTIC OF THE CAR

Traction characteristic of the car was the dependence between the propelling force on the car wheels on its linear speed. The propelling force on the car wheels was calculated with the formula:

$$P_k = (M_{o\ theor}\ \sigma\ \eta_m\ i_{bi}\ i_g)/r_k, \quad (1)$$

where:
P_k – propelling force on the wheels [N],
$M_{o\ theor}$ – theoretical engine torque (value according to the trend curve) [Nm],
σ - under-hood power loss factor,
η_m – mechanical efficiency of propelling system,
i_{bi} – ratio of the actual gear of the gearbox the car is driving at (selectable ratio),
i_g – final drive ratio (permanent ratio),
r_k – wheel kinematic radius [m].

The car velocity was described with the dependence:

$$V=(0.38\, n_s r_k)/ i_{bi}\, i_g\ , \tag{2}$$

where:
V – car linear velocity [km/h],
n_s – engine rotational speed [min^{-1}],
r_k – wheel kinematic radius [m],
i_{bi} – ratio of the actual gear of the gearbox the car is driving at (selectable ratio),
i_g – final drive ratio (permanent ratio).

The values of the propelling force and the linear velocity were calculated for five gears. The reverse gear was not taken into account.

The graph shows the vehicle motion resistances, i.e. rolling resistance, air resistance and grade resistance. The resistance curves were drawn based on dependences available in the literature [1,4,8,12,14].

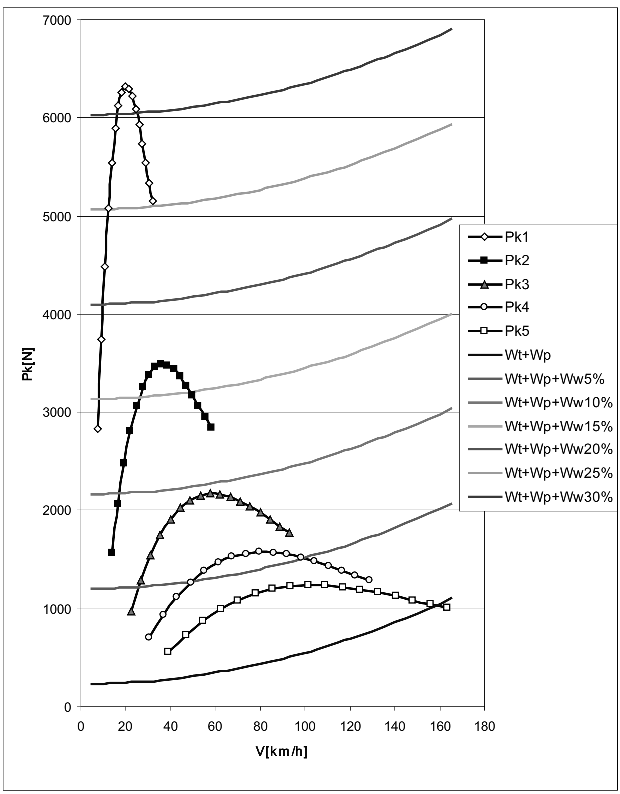

Fig. 3. Traction graph of a Fiat Panda car equipped with a 1.3 JTD engine
Pk1, Pk2, Pk3, Pk4, Pk5 – propelling force for the subsequent gears: 1, 2, 3, 4, 5;
Wt– rolling resistances; Wp – air resistance; Ww% - grade resistance
(e.g. Ww 5% - grade resistance at a 5% slope)

RESULTS

Maximum speed of the car: 155 km/h.
Maximum propelling and acceleration forces at individual gears:

Table 4. Maximum propelling and acceleration forces at individual gears

	$P_{k\,max}$ [N]	a [m/s^2]
gear 1	6318.28	3.21
gear 2	3488.07	1.77
gear 3	2173.98	1.10
gear 4	1574.32	0.80
gear 5	1238.12	0.63

where: $P_{k\,max}$ – maximum value of propelling force at the given gear, a – maximum value of acceleration at the given gear

Steepest hill possible to overcome at gear 1: 30 %.
Steepest hill possible to overcome at gear 2: 15 %.
Steepest hill possible to overcome at gear 3: 5%.
Steepest hill possible to overcome at gear 4: 5%.

CONCLUSIONS

Considering the fact that it was not a sports car, its maximum speed (155 km/h) was of a satisfactory level. Apart from the engine and propelling system design, that was strongly attributed to the aerodynamics of the vehicle. The basic air resistance factor had been effectively reduced throughout the years, thanks to which the car had been achieving higher and higher maximum speeds and using less and less fuel.

The ability to overcome a 30 % slope when fully loaded proved the good selection of the transmission ratio of gear 1 and utilization of the torque characteristics.

Acceleration values achieved at the other gears were important too, whereas the first selectable transmission had a high value.

It its worth consideration if it would not good to have the ratios of gears 2 and 3 increased slightly. This could make the car able to overcome steeper elevations at these gears and to achieve a better acceleration. Particularly, increasing the gear 3 ratio would make sense, as in urban traffic this gear is used most frequently.

On the other hand, increased rations of gears 2 and 3 would result in increased fuel consumption while driving at them. That would entail a general increase of fuel consumption, and thus a higher emission of exhaust gases.

To sum up, in the view of the ecology and economy, the engine and propelling system design should be qualified as good. Traction characteristics of the car result from its intended use.

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ANALIZA WŁASNOŚCI TRAKCYJNYCH SAMOCHODU FIAT PANDA WYPOSAŻONEGO W SILNIK 1,3 16 V MULTIJET

Streszczenie. W artykule przedstawiono analizę własności trakcyjnych samochodu Fiat Panda wyposażonego w silnik 1,3 16 V Multijet. Wykonano charakterystykę pełnej mocy silnika 1,3 JTD wraz z doborem krzywych trendu. Na podstawie krzywej momentu z tego wykresu oraz podstawowych danych pojazdu wyznaczono charakterystykę trakcyjną pojazdu. Była to zależność siły napędowej od prędkości liniowej pojazdu. Na jej podstawie analizowano własności trakcyjne pojazdu Fiat Panda, takie jak: zdolność przyspieszania, możliwość pokonywania wzniesień oraz uzyskiwanie maksymalnej prędkości.

Słowa kluczowe: własności trakcyjne pojazdu, teoria ruchu, silniki spalinowe, charakterystyka zewnętrzna silnika.