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Comparison and selection of electric vehicle propulsion system

Noge Filip · Elektrotechnika, Študentské práce

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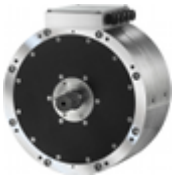

The work compares and evaluates various kinds of electric propulsion for vehicles. At the beginning we set the conditions for comparison. We are interested in output parameters such as acceleration, top speed and gear ratios. Finally, the best system is chosen with an explanation of why this is the best.

1. Introduction – Electro mobility

Low efficiency, limited supply of energy sources, mechanical limits are the main problems related to transportation and automotive industry. Mankind should solve this problem with combustion engine. There are already several concepts to replace the combustion engines and most of them directed to electric vehicles, whether by a plug-in full electric vehicle or a vehicle with a fuel cell. Presently, we still did not replace combustion engines by electro mobility because we have enough fuel and we can not properly store electricity in batteries, but it becomes more and more recent. Therefore, I have decided to choose and propose full electric vehicle.

2. Traction propulsion

The goal was to create the vehicle propulsion, which we comply with the following parameters in order of priority: acceleration, maximum speed, as low weight. The task is to select a suitable motor and project propulsion system. The system has been solved under following circumstances which are shown in the table 2.1.

Tab. 2.1. Circumstances for calculations

Circumstances for calculations			
gravitational acceleration	g	9,81	$m.s^{-2}$
air density	ρ_o	1,22	$kg.m^{-3}$
air resistance coefficient	c_x	0,3	
rolling resistance coefficient	f_v	0,01	
coefficient of rotational mass inertia	δ	0,5	
frontal area of vehicle	S	1,2	m^2
vehicle weight	m	1200	kg

wheel dynamic radius	r_d	0,3	m

Tab. 2.2. Main equations and units.

Basic equation	Units	Used equation	Units
$P = M2\pi n$	[P]=W [M]=Nm [n]=s^{-1}	$P = \frac{M2\pi n}{6000}$	[P]=kW [M]=Nm [n]=ot/min
$F = \frac{Mi_c}{r_d}$	[F]=N [M]=Nm [r_d]=m	$F = \frac{Mi_c}{r_d}$	[F]=N [M]=Nm [r_d]=m
$v = \frac{2\pi r_d n}{i_c}$	[v]=ms^{-1} [rd]=m [n]=s^{-1}	$v = 3.6\frac{2\pi r_d n}{60 i_c}$	[v]=km/h [rd]=m [n]=ot/min

The next chapter contains three best electro-motors in matter of performance in comparison to many other available motors.

3. EVO 240

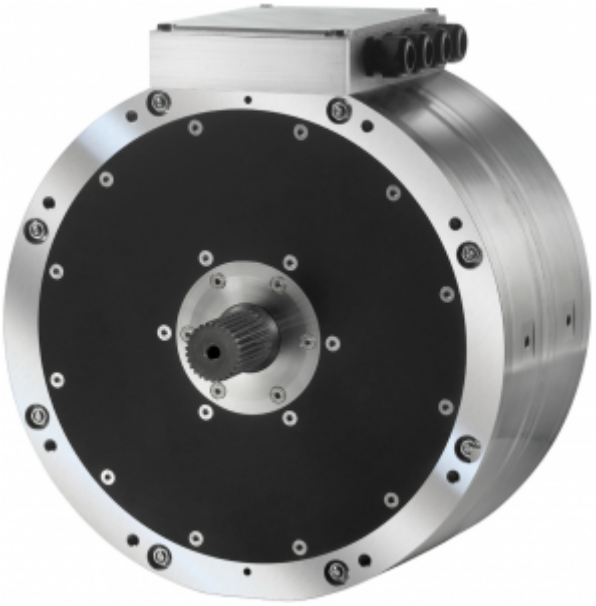

Fig. 3.1 Image of the EVO 240 electric motor

3.1 Parameters of the EVO 240

Tab. 3.1. EVO 240 specifications

MOTOR	
Dimensions	L 222 D 400 mm
Maximal peak torque	800 Nm
Maximal peak power	335 kW
Maximal nominal torque	440 Nm
Maximal nominal power	150 kW
Maximal RPMs	5000 ot/min

Weight	80 kg
Maximal efficiency	96,5%
INVERTOR	
Dimensions	643x340x166 mm
Voltage range	300-720 V
Maximal current	343 A
Weight	30 kg

3.2 Characteristics of the EVO 240

Tab. 3.2. EVO 240 performance curves table

torque and power vs. RPMs				
P_{nom}	**M_{nom}**	**P_{max}**	**M_{max}**	**n**
0,00	440,00	0,00	800,00	0
22,51	430,00	41,89	800,00	500
43,98	420,00	83,78	800,00	1000
54,32	415,00	104,72	800,00	1250
64,40	410,00	125,66	800,00	1500
83,78	400,00	167,55	800,00	2000
102,10	390,00	209,44	800,00	2500
119,38	380,00	251,33	800,00	3000
135,61	370,00	293,22	800,00	3500
150,80	360,00	335,10	800,00	4000
150,80	320,00	341,65	725,00	4500
146,61	280,00	340,34	650,00	5000

where: M_{max} is peak torque [Nm], P_{max} is peak power [kW], M_{nom} is nominal torque [Nm], P_{nom} is nominal power [kW], n is RPMs [1/min]

Tab. 3.3. Table of total gear ratios for EVO 240

Total gear ratios	i_{c1}	4
	i_{c2}	3,375
	i_{c3}	2,75
	i_{c4}	2,125
	i_{c5}	1,5

Where i_{cx} is the total gear ratio of gear with corresponding index. The vehicle is approximately able (with this motor and gearing) to achieve an average acceleration 9,78 ms^{-2}, which means acceleration from 0 to 100 km/h in 2,84 s on the first gear.

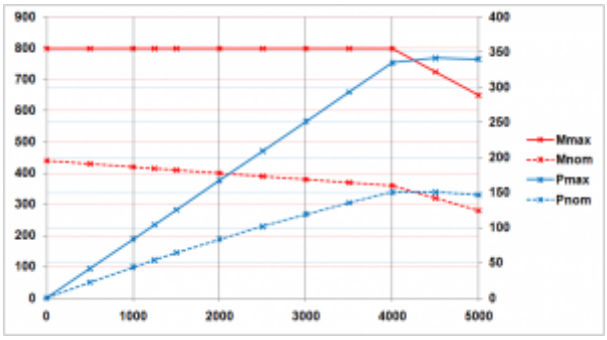

Fig. 3.2. EVO 240 performance curves

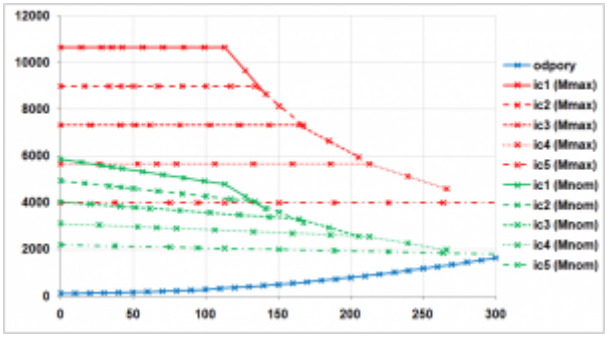

Fig. 3.3. EVO 240 propulsion force vs. RPMs chart

3.3 Appreciation, advantages and disadvantages of the EVO 240

This motor with its properties are on the leading positions in comparison with other motors, and although it too expensive it has very good torque to price ratio as well as power to price ratio and I assume that in terms of parameters is the most appropriate candidate from analyzed motors.The advantages of this motor are its small size, light weight, excellent parameters and performance curves, and also that it is supplied with an inverter designed exactly for this motor.

Disadvantages are high cost and complicated availability. An interesting fact is the starting torque during short time current overload, which the other motors datasheets do not contain. Its value is 1200 Nm for 18 seconds, so we could use this as a benefit in our application. (peak torque is the motor able to withstand for 60 seconds).

3.4 The cooling requirements of the EVO 240

The motor requires liquid cooling and its structure includes cooling system. Only the pipe connections with coolant and adequate volumetric flow need to be provided for the system startup. The maximum value of volumetric flow rate could not exceed 12 l / min. Mixture of water with ethylene glycol (antifreeze standard component of coolant in the automotive industry) in a 1:1 ratio is recommended as the cooling medium.

4. UQM 200

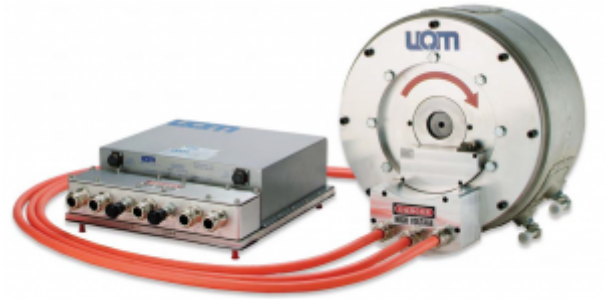

Fig. 4.1 Image of the UQM 200 electric motor

4.1 Parameters of the UQM 200

Tab. 4.1. UQM 200 specifications

MOTOR	
Dimensions	L 241 D 411 mm
Maximal peak torque	900 Nm
Maximal peak power	200 kW
Maximal nominal torque	450 Nm
Maximal nominal power	115 kW
Maximal RPMs	5500 ot/min
Weight	95 kg
Maximal efficiency	94%
INVERTOR	
Dimensions	380x365x119 mm
Voltage range	240 – 440 V
Maximal current	600 A
Weight	15,9 kg

4.2 Characteristics of the UQM 200

Tab. 4.2. UQM 200 performance curves table

torque and power vs. RPMs				
P_{nom}	**M_{nom}**	**P_{max}**	**M_{max}**	**n**
0	455	0	900	0
24	455	48	900	500
48	455	96	900	1000
54	440	120	900	1250
66	425	132	860	1500
82	400	160	760	2000
98	375	176	680	2500
115	360	190	600	3000
115	320	200	550	3500

115	270	200	480	4000
108	240	200	440	4500
96	185	200	380	5000

where: M_{max} is peak torque [Nm], P_{max} is peak power [kW], M_{nom} is nominal torque [Nm], P_{nom} is nominal power [kW], n is RPMs [1/min]

Tab. 4.3. Table of total gear ratios for UQM 200

Total gear ratios	i_{c1}	4
	i_{c2}	3,75
	i_{c3}	3
	i_{c4}	2,25
	i_{c5}	1,5

Where i_{cx} is the total gear ratio of gear with corresponding index. The vehicle is approximately able (with this motor and gearing) to achieve an average acceleration 9,84 ms^{-2}, which means acceleration from 0 to 100 km/h in 2,82 s on the first gear.

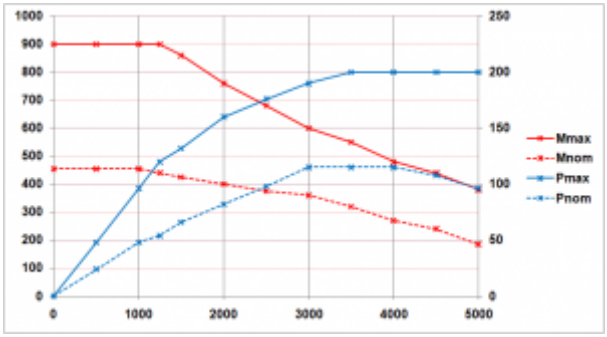

Fig. 4.2. UQM 200 performance curves

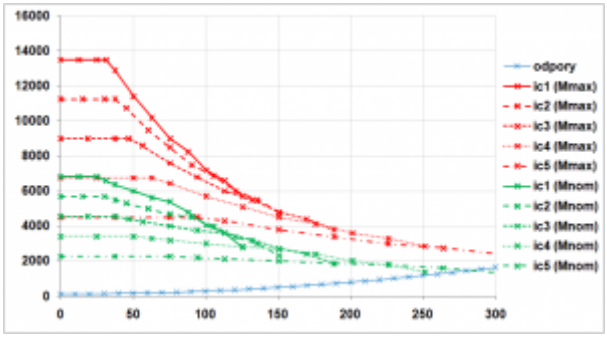

Fig. 4.3. UQM 200 propulsion force vs. RPMs chart

4.3 Appreciation, advantages and disadvantages of the UQM 200

This motor has the highest value of torque in comparison to others considered, this means it has the highest value of torque, and although it is quite expensive it has a very good torque to price ratio as well as power to price ratio and I assume that in terms of parameters is the most appropriate candidate from analyzed motors.

The advantages of this motor are its small size, light weight, excellent parameters and performance curves, and also that it is supplied with an inverter designed exactly for

this motor. Disadvantages are high cost and complicated availability. Possibility of short time current overload and also the time period that the system could withstand are unknown.

4.4 The cooling requirements of UQM 200

The motor requires liquid cooling and its construction includes cooling system. Only the pipe connections with coolant and adequate volumetric flow need to be provided for the system startup. The maximum value of volumetric flow rate should not exceed 7,5 l / min and maximum value of pressure in cooling system should not exceed 0,7 bar. Mixture of water with ethylene glycol (antifreeze standard component of coolant in the automotive industry) in a 1:1 ratio is recommended as the cooling medium.

5. Symetron P-200

Fig. 5.1 Image of the Symetron P-200 electric motor

5.1 Parameters of Symetron P-200

Tab. 5.1. Symetron P-200 specifications

MOTOR	
Dimensions	L 457 D 279 mm
Maximal peak torque	415 Nm
Maximal peak power	200 kW
Maximal nominal torque	207 Nm
Maximal nominal power	100 kW
Maximal RPMs	5500 ot/min
Weight	112 kg
Maximal efficiency	93%
INVERTOR	
Dimensions	224x330x358 mm
Voltage range	500 – 700 V
Maximal current	? A
Weight	36 kg

5.2 Characteristics of the Symetron P-200

Tab. 5.2. Symetron P-200 performance curves table

torque and power vs. RPMs				
P_{nom}	**M_{nom}**	**P_{max}**	**M_{max}**	**n**
0,00	207,00	0,00	415,00	0
10,84	207,00	21,73	415,00	500
21,68	207,00	43,46	415,00	1000
32,52	207,00	65,19	415,00	1500
43,35	207,00	86,92	415,00	2000
54,19	207,00	108,65	415,00	2500
65,03	207,00	130,38	415,00	3000
75,87	207,00	152,11	415,00	3500
86,71	207,00	173,83	415,00	4000
97,55	207,00	195,56	415,00	4500
97,91	187,00	198,97	380,00	5000
97,91	170,00	201,59	350,00	5500
97,39	155,00	201,06	320,00	6000
95,29	140,00	199,44	293,00	6500
93,10	127,00	197,92	270,00	7000
93,46	119,00	196,35	250,00	7500
92,15	110,00	196,87	235,00	8000
93,46	105,00	195,83	220,00	8500
94,25	100,00	197,92	210,00	9000
95,50	96,00	201,95	203,00	9500
99,48	95,00	204,20	195,00	10000

where: M_{max} is peak torque [Nm], P_{max} is peak power [kW], M_{nom} is nominal torque [Nm], P_{nom} is nominal power [kW], n is RPMs [1/min]

Tab. 5.3. Table of total gear ratios for Symetron P-200

Total gear ratios	i_{c1}	9
	i_{c2}	7,375
	i_{c3}	5,75
	i_{c4}	4,125
	i_{c5}	2,5

Where i_{cx} is the total gear ratio of gear with corresponding index. The vehicle is approximately able (with this motor and gearing) to achieve an average acceleration 9,44 ms^{-2}, which means acceleration from 0 to 100 km/h in 2,94 s on the first gear.

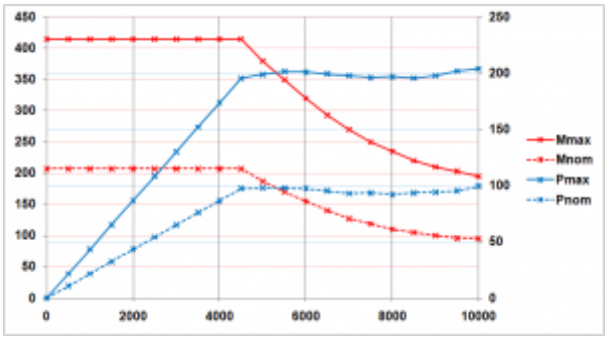

Fig. 5.2. Symetron P-200 performance curves

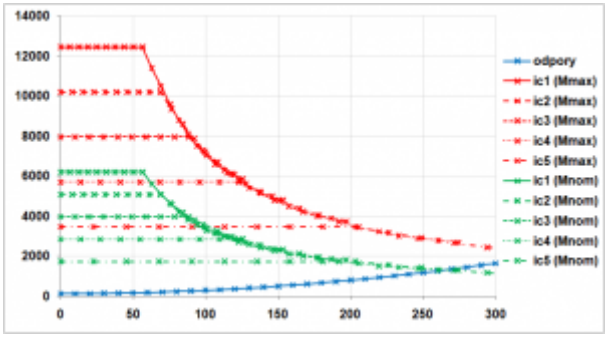

Fig. 5.3. Symetron P-200 propulsion force vs. RPMs chart

5.3 Appreciation, advantages and disadvantages of the Symetron P-200

The motor including its parameters is above average but not apparently excellent, which is not a problem if they are sufficient, so this should be well considered. Its advantage is the relatively high power and broadband RPMs. The main disadvantages are high weight, a high supply voltage and relatively large dimensions. Torque value is lower, but still sufficient.

5.4 The cooling requirements of the Symetron P-200

Cooling is provided by fluid coolant that is used in most of motors. Details of cooling are not known. Mixture of water with ethylene glycol (antifreeze standard component of coolant in the automotive industry) in a 1:1 ratio is recommended as the cooling medium.

6. Conclusion

First of all let’s look at gearbox. We can say, that it is necessary to implement gearbox, because it provides the opportunity to achieve excellent acceleration and high value of maximal speed, so that is the reason why we do not want to use permanent ratio or without any ratio conception. There is one solution that could be comparable to conception with gearbox. It is conception with two motors without gearbox (or with permanent ratio). This conception has major problem with power consumption. It means that two motors consume twice value of energy. This solution requires more batteries and cause more weight. That is the reason why we incorporate the gearbox.

Now let’s look at the motor choice. From all the candidates we choose the EVO 240 as the best alternative. It has great performance curves and it is relatively lightweight.

There might be a question, if the gearbox is strong enough to transfer high torque that the motor provides. We should not forget that the calculations were provided not considering the losses (efficiency). This means that the real result value will be lower, but to compare the systems the calculations are appropriate.

References

1. http://www.evo-electric.com/products/
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Coauthor of this paper is Ing. Vladimír Staňák, Katedra mechaniky, Fakulta elektrotechniky a informatiky, Slovenská technická univerzita, 812 19 Bratislava, Slovenská republika

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