DESIGN OF AN ELECTRIC TRACTION DRIVE FOR A MICRO CAR JAWA CHIC

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ABSTRACT

The aim of this contribution consists in a choice of a suitable motor type used in a traction drive for an electric vehicle based on a microcar JAWA CHIC. Basic advantages and disadvantages of some usable motors are discussed (induction, synchronous with PM, DC with PM). An induction machine was chosen as a result of this analysis. The motor will be driven with a DC/AC inverter. Hydrogen fuel cells combined with an accumulator will crearte the energy source for the inverter.

Further the calculation of the required torque-speed course with respect to the required maximum power, maximum vehicle speed, road grade ability and losses (rolling friction, air resistance) are included. The size of the induction machine, its nominal point and following transfer gear ratio are designed on the base of this calculation.

1. INTRODUCTION

The maximum possible efficiency of the whole system motor + gear, minimum mass and dimensions at a given torque-speed course are the main requirements on the vehicle drive.

Contradictory criterions for the transfer gear ratio: The gear ratio has to guarantee the maximum required torque on the wheel axis at the nominal motor torque. A low nominal motor torque is reguired to achieve a low motor weight. However at a high speed a high motor speed is forced with such a high gear ratio. A too high maximum motor speed could bring problems with the motor or gear construction and it could cause high mechanical losses.

2. DRIVE DIMENSIONING

2.1. MACHINE TYPE

Advantages and disadvantages of several motor types will be discussed. Three motor types can be taken under discussion: DC with PM, synchronnous with PM, squirrel cage induction motor.

2.1.1. DC MOTOR WITH PERMANENT MAGNETS

Advantages:

- an excellent ratio nominal torque/weight (standard. 1Nm/kg)
- a simple way of driving, a simple DC/DC converter

Disadvantages:

- irremovable eddy curent and hysteresis losses in the magnetic circuit at a high speed
- the machine includes a commutator – needs servicing, friction losses of commutator

2.1.2.SYNCHRONOUS MACHINE WITH PERMANENT MAGNETS

Advantages:

- a excellent ratio nominal moment/weight (type. 1Nm/kg),
- a high efficiency in a regime with a high torque and low speed
- brushless machine

Disadvantages:

- a practical impossibility to deexcite the machine, hysteresis and eddy curent losses
- a complicated DC/AC supply inverter requiring a position sensor of the rotor

2.1.3.INDUCTION SQUIRREL CAGE MOTOR

Advantages:

- the lowest price
- a possibility to deexcite the machine at a higher speed

Disadvantages:

- an excitation from stator – additional ohmic losses in the winding,
- the ratio torque/weight ca 3-5x lower than the previous machines

We use the induction motor because of its price and possibility of field suppression at a higher speed.

2.2. Drive with the induction motor

2.2.1. Number of poles

The choice of stator poles can be deduced from following facts. The motor size corresponds to its torque but not power. A certain power can be achieved at a given torque changing the speed so changing the frequency (at a constant flux density). The pole number has theoretically no influence on the ratio size/torque. However practically the reachable torque increases a bit with the increasing number of poles (a shorter magnetic circuit, a better usage). An increasing number of poles at a given constant power and torque represents a frequency growing at the constant flux density. This brings a growth of stator iron losses. This is why the choice of number of poles must be a compromise between a good usage of the magnetic circuit (a higher number of poles required) and favourable low hysteresis and eddy current losses in the stator (frequency as low as possible - number of poles as low as possible). The 4-pole machine is an acceptable solution of this compromise at the discussed power size.

2.2.2. Motor power calculation

These input parameters (deduced from the vehicle properties) are given:

P_{max}=5kW – maximum required motor power

M_{min}=53Nm – min. loading torque when riding on a horizontal road at the maximum speed 80km/h (on axis of the wheel, caused with the rolling friction and air resistance)

M_{max}=140Nm – max. loading torque when riding up to a hill with 12% climb (on axis of the wheel)

A small machine with a relatively low nominal torque must be used because of the low requred weight. A 4-pole machine 1LA9096-4LA Siemens (weight 18kg) will be used. The nominal torque is M_{jm} = 17 Nm. The corresponding nominal power is 2500W (at the nominal line freqeuncy f_s = 50 Hz - at the nominal speed n_{as} = 1490 rpm). These parameters are true for the winding Y-connected what means the amplitude of the coil (phase) voltage U_{max} = 230 . √2 V = 325 V. The nominal electric slip frequency corresponding to f_s and n_{as} is f_{slip}=0,33Hz.. The re-winding of the machine enables the nominal speed increasing at the changed line voltage and at the preserved constant flux density (preserved torque). This brings the desired power increasing up to 5kW. At a low speed we can increase the torque using an over-exciting (without any slip increasing) about 40%. That´s why we can suppose the maximum machine torque 23,8Nm instead of 17Nm. A lower necessary gear ratio will be achieved - so a favourably lower maximum speed (at the maximum vehicle speed). This over-excited motor regime will be allowed in the speed range from 0 up to only 2000rpm in order to disable the power to exceed 5kW.

We have to design the gear ratio before we design the nominal point of the motor. If the maximum wheel torque 140Nm is required and the overexcited machine allows 23,8Nm then the total gear ratio must be:

$$p = \frac{140Nm}{23,8Nm} = 5,9 \qquad (1)$$

Then the maximum speed of the rotor at the maximum wheel speed ca. 900rpm (80km/h) will be:

$$n_{\max} = p \cdot 900 rpm = 5{,}9 \cdot 900 rpm = 5310 rpm \qquad (2)$$

It's practically tested that such a speed is acceptable for the rotor without its lifetime shortening. The induction machine driven from a DC/AC inverter can operate with a constant flux density (so with a constant nominal torque) at the speed range from 0 up to the nominal speed (nominal point). We have to increase the line voltage amplitude in this speed range proportional to the speed(U/f course) to achieve the mentioned constant flux density. At the nominal speed the line voltage is as high as possible - the inverter operates with the full duty-cycle. This is why at a higher spped than is the nominal point the voltage can not be increased any more and the motor will be deexcited. The torque is theretically proportional dependent on the flux density and therefore it decreases hyperbolically (if the speed exceeds the nominal point). The breakdown torque is dependent on the square of the flux density and that is why when exceeding the nominal point it decreases faster than the motor torque. If the discussed minimal motor torque (at the maximum speed) should be really achieved then the breakdown torque must be always higher than it.

A relation for the minimum possible nominal speed can be deduced from the description above:

$$n_{jm} = \sqrt{\frac{M_{\min}}{M_{Zjm}}} \cdot n_{\max} = \sqrt{\frac{9}{39{,}1}} \cdot 5310 rpm = 2547 \mathrm{rpm} \qquad (3)$$

Now we must calculate the nominal speed to reach the power 5kW:

$$n_{jm} = \frac{60P}{2\pi\ M_{jm}} = \frac{60 \cdot 5000}{2\pi\ 17} = 2810 \mathrm{rpm} \qquad (4)$$

The minimum allowed nominal speed (because of the breakdown torque drop) is lower than the nominal speed to achieve the power 5kW, what is OK and it enables to use really the speed 2810rpm as the nominal point. The winding will be calculated using this nominal speed value.

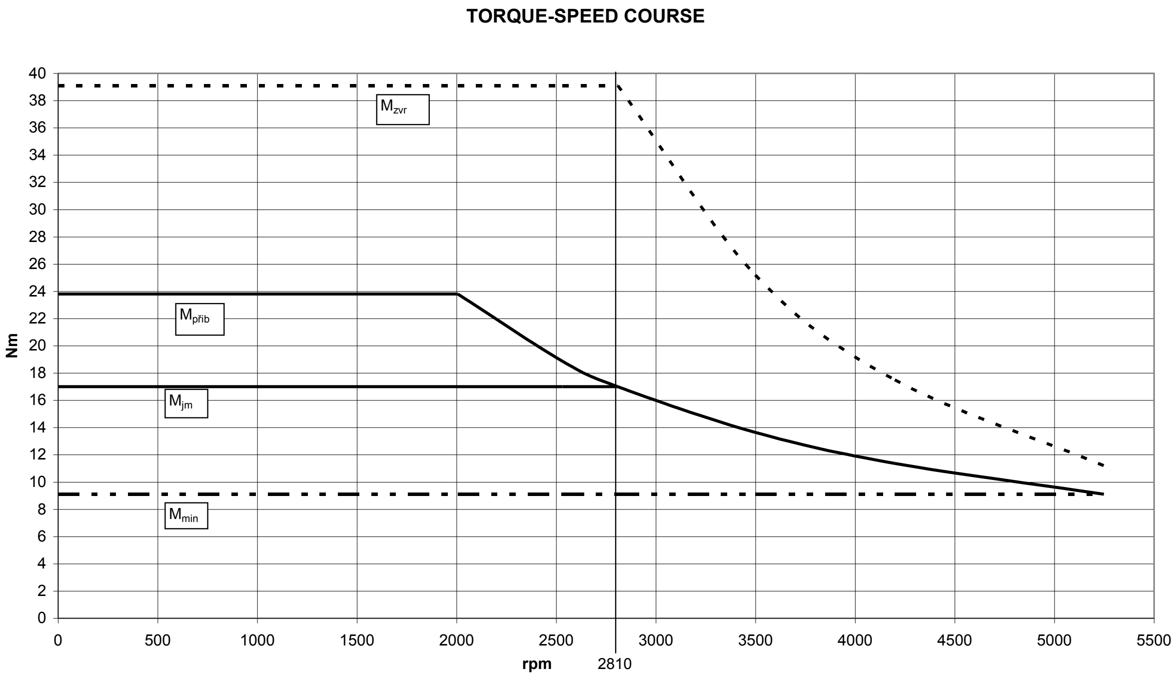

Fig.1.:Determination of motor type.

3. CONCLUSION

The nominal speed and torque of the machine were designed. The corresponding synchronous el. frequency is 94Hz (preserving the original slip frequency). The winding calculation will continue. The machine will operate with a twice-increased nominal speed than in the original so with a double power. The power increasing is achieved preserving the weight 18kg. The motor will be installed instead of the original combustion engine whose weight was higher. This weight reserve will be used for fuell cells and accumulators.

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