RESEARCH OF ELECTRIC MOTOR MECHANICAL LOSSES

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ABSTRACT

This article presents optimization procedure and details of design variations which arise during the development of the propulsion system of different kind of electric vehicles. The mathematic model of the drive unit and electric motor has been set up for the efficiency optimization of propulsion system, which helps to determine the power loss of each construction.

1 INTRODUCTION

The development of different performance electric and hybrid motors has been in progress at Széchenyi István University of Győr for many years. The developments run in several directions, from vehicle driving PMS motor, through vehicle communication system, to bodywork. Nowadays, the key problem of electric vehicles is the energy storage and it follows the short range usage, which necessitate the further research of energy efficiency. The most important part of the energetic research is the investigation of the propulsion system, which, in most cases, includes the PMS motor and its propulsion. It's difficult to define the necessary transmission and drive unit for given vehicle, so it's indispensable to carry out complex analysis. If drive unit required, the design and selection are the major problems to be solved. The difficulty of the design is that the efficiency of the drive unit is usually considered constant, while this value shows a significant change during the working process. Therefore it's appropriate to set up a mathematical model, which helps for the efficiency optimization of the propulsion system.

2 THE OPTIMALISATION MODEL

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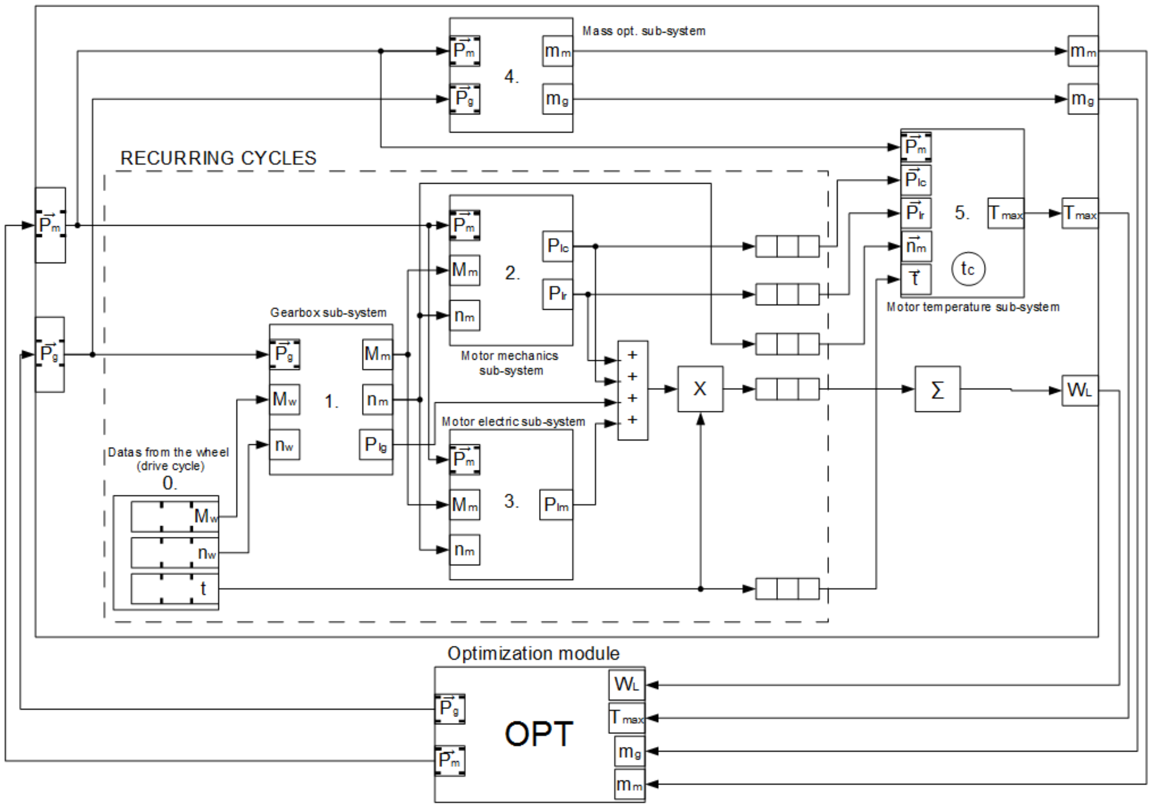

Figure 1. The optimization system

The model inputs are the following parameter vectors:

Driving unit

$$p[i, m, a_w, b, \alpha, \beta]$$

- i: gear ratio of the propulsion system
- m: module
- aw: actual wheelbase
- b: gear width
- α: switching angle
- β: obliquity angle of the teeth

Motor

$$p[Di, Do, \dots \dots . mf]$$

- Di: inner stator diameter
- Do: outer stator diameter
- a: air gap
- mt: magnet thickness
- rt: rotor thickness

- g: teeth gap
- t: tooth height
- sd: groove depth
- swl: inner groove width
- sw0:outer groove width
- l:motor length
- N:number of threads
- d:conductor diameter
- p:number of poles
- mf: magnetic filling factor of the motor

It basically consists of 6 sub-systems:

- initial sub-system (wheel torque and wheel speed values)
- driving unit sub-system
- motor's mechanical sub-system
- motor's electrical sub-system
- mass optimization sub-system
- motor temperature sub-system

Torque-speed values are calculated from speed-time and torque-time values, so the operation points of the driving cycles can be described in the workspace of motor (torque-speed coordinate system). Nevertheless, the application in that form is not possible during this optimization process, that's why we use rare segmented histogram, which allows investigating less operating points during the motor design process. The wheel torque and wheel speed values are derived from a previously defined (expected) driving cycle. (0. Sub-system) [2]

The model of the driving unit was set up to determine the losses by investigating constant conditions on the operating point. (1. Sub-system)

The sub-system of the motor was divided into 2 parts, an electric and a mechanical one. (2. and 3. sub-system)

These functions and the sub-system run cyclically on every operating point. The 4. Sub-system works based on the previous results, which helps in the mass optimization. 5. Sub-system determines the heat and the derived maximal temperature during the cycle, with combined application of the motor and driving unit on the given operating point.

The first step of the optimization is to determine a driving unit and a motor, based on parameter vectors, then determine the losses on a selected operating point, which consist of the mechanical losses of the driving unit, and the mechanical and electrical losses of the motor. Knowing the losses, the efficiency of the driving unit-motor pair can be determined on the given operating point. [1,2,3]

$$\eta_{(n_{vw},T_{vw})} = \frac{P_{in(n_{vw},T_{vw})} - W_{l(n_{vw},T_{vw})}}{P_{in(n_{vw},T_{vw})}}$$

The energy that directed to the propulsion system by the motor on the given operating point

$$P_{in(n_{vw},T_{vw})}$$

After running, we could change the parameters, and then we run it again. We should repeat until we find the parameter vectors with lowest rate of energy losses, and the belonging physical units.

3 MECHANICAL LOSS OF THE DETERMINATION OF MOTOR

The source of losses can be divided according to load and speed sensitivity.

Load sensitive losses:

Load and speed sensitive losses:

Bearing friction losses: Wsv,

Speed sensitive losses:

Gasket's friction losses: Wtsv,

Lubricant mixing losses: Wkv,

Air convection losses: Wlv,

Total loss of the driving unit can be determined by summarizing each loss on a given operation point.

$$W_v = f(n, M)$$

Total loss of driving unit: W_v

It follows that, the losses of driving unit can be determined in a constant condition.

$$W_v = W_{sv} + W_{tsv} + W_{kv} + W_{lv}$$

In case of investigation the losses of the vehicle's driving unit, it's worthwhile to select operation points from the determined driving cycle. So as We have presented before, the operation points can be determined from the tractive power and speed.

$$W_l = f(n_w, M_v)$$

The vehicle's speed at a given operation point: $n_{vw,}$

The vehicle's torque derived from the tractive power of the given operation point: T_{vw}

4 SUMMARY

In the article I have presented the optimization model of the electric motor- drive unit designed for driving cycle, which was developed at the Széchenyi István Universiy of Győr. I have also dealt with the mechanical losses of the electric motor. In the following, we will carry out the implementation of the model in MATLAB and CAD-FEM environment. In the presentation We are going to demonstrate the results of that implementation.

5 REFERENCES

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