ANALYSIS AND DESIGN OF DC MOTOR AND GEAR FOR TRUCK WIPER SYSTEMS

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ABSTRACT

This contribution is dedicated to innovation of wiper drive. The drive consists of direct current motor with permanent magnet and a gear. Main goal of the project was to increase starting torque of the motor and to ensure self-locking output of the gear. Present state of the wiper drive cannot pretend proper function with today wipers, which has about hundred centimeters length (e.g. busses, trucks). Main problems appear especially during winter when ice on the front window cause heavy increase of load torque. Also during fast drive, wind gusts cause quick changes of load torque. These two problems cause fluctuations of the wipers on the front window in orders of centimeters.

The problem has been solved in these main steps:

- original drive description
  - analysis of current state, deficiencies
  - requests for improvement
  - characteristics measurement of motor and whole drive
- electro-mechanic analysis of new motor
  - development of calculating program, comparison with original motor
  - design of new motor
  - prototype production
  - laboratory tests and comparison with calculations
- development of new gearbox, cooperation with Faculty of Mechanical Engineering
  - analysis of construction possibilities
  - produce of test device
  - construction of gear prototype
- working life tests of the drives

- original gear tests – Wöhler curves
- new gear tests, comparison of results

- development of electronic speed control

All these steps are fully described below.

1 ORIGINAL DRIVE DESCRIPTION

The original wiper is driven by direct current motor with ferrite permanent magnets. Two different speeds of the motor are ensured by two separate windings, two brush holders and two commutators. This was at first glance main disadvantage of the motor that should be corrected during future development. Another important minus was from customers point of view planet gear on the output of drive, where occurs small angle backlash. It can cause even several centimeters offsets on the end of nearly hundred centimeters long wipers, which are used at present. Another deficiency is in stating torque of the drive, that can make problems with such long wipers especially during fast drive (strong wind), or in winter (icing on the windscreen).

Due to lack of technical specifications was necessary to make tests of the original drive before design of new type of drive was started. For these measurements was delivered three pieces of wiper drive. First think first was measured whole drives (motor and gearbox). These measurements allow to determinate efficiency of whole drive. Average measurement results of the three drives were drawn to graphs as output and mechanical drive characteristics. After that was tested only the motors and again was determinate their most important parameters, which were needed for new motor calculation (starting torque, nominal current, efficiency, …). Individual characteristics were again drawn to graphs for better comparison (Fig.1). From efficiency of the motor and the drive was calculated efficiency of the gearbox that has also dramatic effect to downgrade of overall energetic balance of the drive.

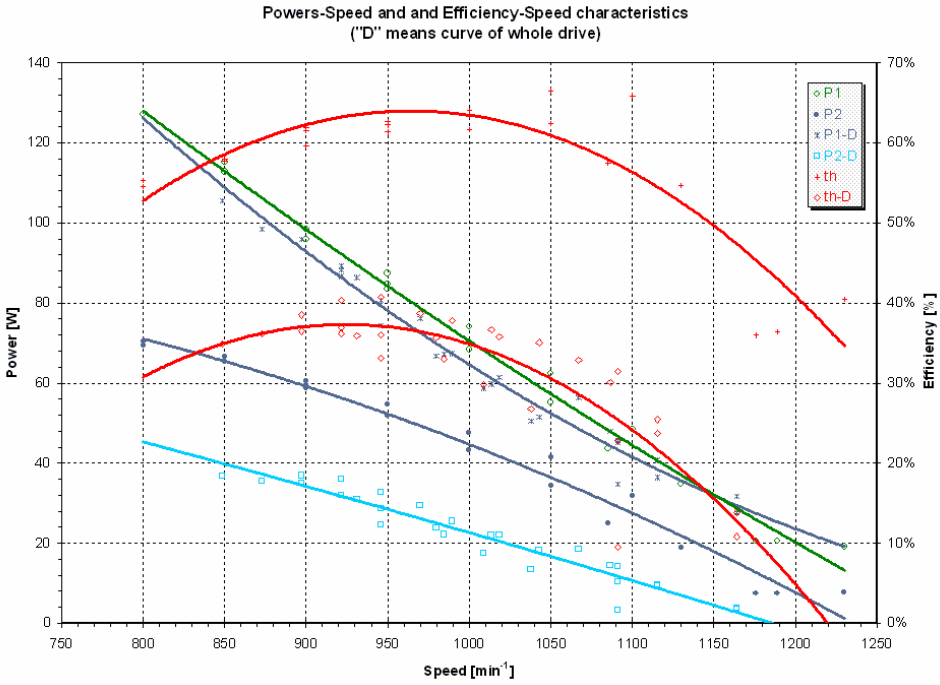

Fig. 1: *Power-Speed and Efficiency-Speed characteristics - original motor*

2 ELECTRO-MECHANIC ANALYSIS OF NEW MOTOR

Another step in the new drive design was theoretical design of the motor and the gear. For such calculations any of "universal" computational program does not meet our requirements, so it was necessary to develop such program. Because the main point was just functionality of calculation for the specific problem, program has been developed in spreadsheet processor Microsoft Excel. Right functionality of the program was firstly verified by check calculation of original type of motor and calculated characteristics were compared with measured once.

According to requirements of firm APS, was laid stress on maximal observance of current motor dimensions. It turned out that for torque increase at constant motor diameter was necessary to extend rotor and length of magnet. For increase of input power and in consequence of output power, was thickened rotor winding. Both operations could be realized providing that the second winding of the rotor and commutator will be removed – the control of motor speed will be performed otherwise. Final characteristic of new calculated motor is shown on figure No.2. For nominal torque (approx. 0,8N.m) was achieved maximal efficiency of the motor.

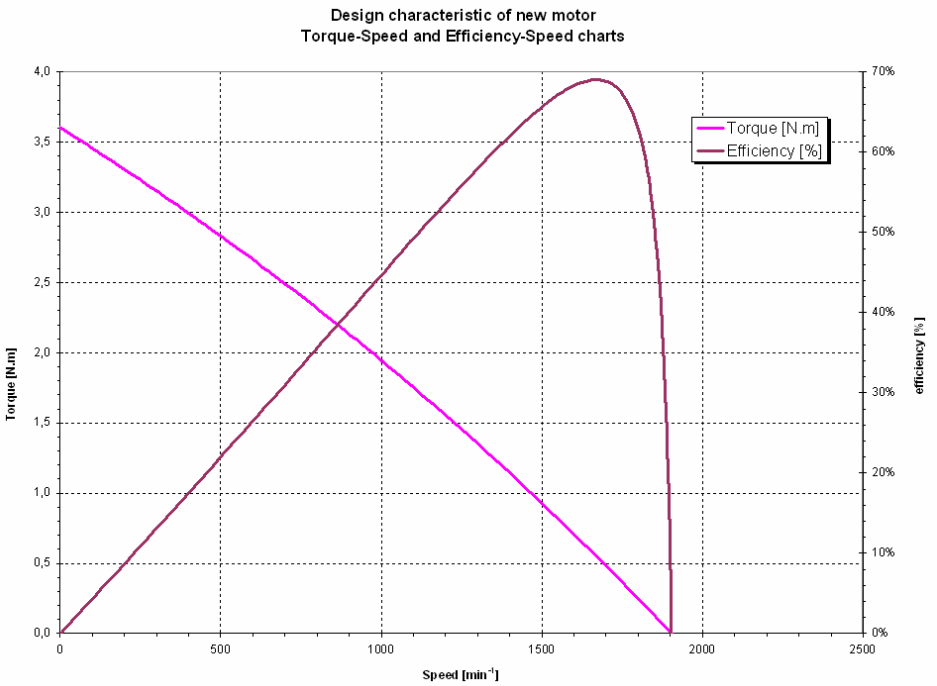

Fig. 2: *Torque-Speed and Efficiency-Speed characteristics – calculated motor*

After realization of the calculations was with support of firm APS designed a prototype of the motor. For verification of calculations were again mechanical characteristics of motor measured. The results are for comparison shown in graph together with characteristic of original motor (Fig. 3). After comparison of calculated and measured results is evident that motor prototype is very similar to calculated model of motor.

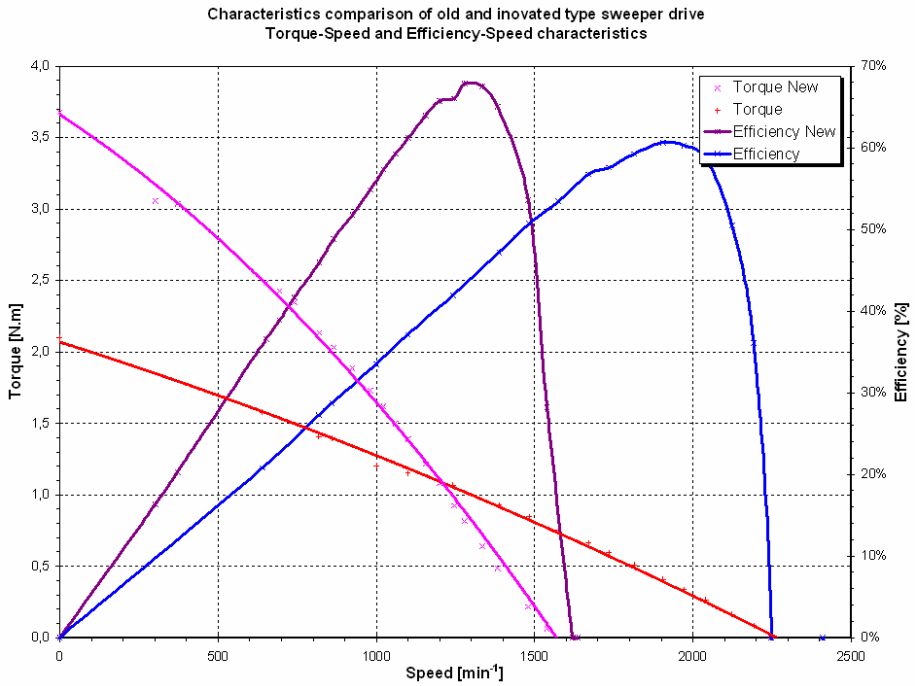

Fig. 3: *Torque-Speed and Efficiency-Speed characteristics – comparison of original and new motor*

3 DEVELOPMENT OF NEW GEARBOX, COOPERATION WITH FACULTY OF MECHANICAL ENGINEERING

Because starting torque of the motor is against original one nearly doubled, it was necessary to improve parameters of the gear. Another reason for this was also its too complicated construction, which increase manufacturing costs and also important factor was its weak self-locking on he output. This weak self-locking cause in practice swings of wipers on windscreen.

So during analysis of construction solutions was then instantly excluded the original planet gear, although it has very good efficiency and axial alignment, but it does not meet one of main requirements – self-locking. As a good solution appeared cycloidal gearing, which has self-locking output, axial alignment and also has a very good efficiency. Unfortunately it was also rejected after consultation with specialists from firm APS, for its demands for precision machining and consequently its high manufacturing costs. Such gear causes too much increase of price of whole wiper drive.

The last proposed solution was not very effective, but unexacting for manufacturing worm gear. Such gear seems to be suitable not only from point of its self-locking, but especially from point of cost. Primarily intended three-thread worm was throw off, because its too large dimensions and there was used single-thread worm. After strength calculations performance on Faculty of mechanical engineering were proposed for future testing two types of single-thread worms from for different materials. First type – globoid worm – promised higher strength and efficiency at the expense of more difficult manufacturing and assembly. Second type of worm was vice versa more simple and allowed easier finishing, eventually simpler form (in dependence on used material).

4 WORKING LIFE TESTS OF THE DRIVES – WÖHLER CURVES, COMPARISON OF RESULTS

Since the working life of the gear in dependence on load was not known, it was necessary to perform these tests for comparison with the new gear. For this purpose was developed with cooperation with firm APS, Světlá nad Sázavou, breaking device, where cycles of wiper with different load could be simulated. As a result of these destructive tests was hyperbolic Wöhler's working life curve. For easier measurement was the curve picked-up as course of current and its maximal, average and steady-state values in every cycle was recorded. Measured current values were possible to transfer to corresponding values of torque, from earlier measured values of motor. Because it was only a comparative measurement, such little inaccuracy could be accepted.

In the same way was made the test of new gear. It was made step by step for both types of gears (globoid, strait gearing) and also for all four different types of material. Regarding to strength of this new gear had not been possible to perform enough tests for proper Wöhler's curve drawing – new gear withstands several fold bigger load. From these several measurements was then chosen the material. From the experiment was also found, that globoid gear has indeed better resulting strength of gearing, but this benefit is not so heavy regarding to difficulty of manufacturing – was chosen the worm gear with straight gearing.

5 DEVELOPMENT OF ELECTRONIC SPEED CONTROL

The last solved problem in the development of the wiper drive was the replacement of second winding and commutator of original motor by other system, which could allow wiping of the front windshield with lower speed. As a simplest solution appears to be a usage of an electronic switching of speeds. The whole regulator is conceive as PWM with switching frequency 5kHz and duty 0,7. This duty seems to be most suitable to preservation of original ratio between lower and higher wiping speed.

6 CONCLUSION

At present is the prototype in a stage of final corrections. Only the details of construction of gear-box and other details are solved, such as mounting of electronics, magnets, cable outlet etc. The project will be directed to research of electronically commutated motor in future.

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