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FAST STEPPER MOTOR'S SINGLE-STEP TORQUE RESPONSE

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Summary: *The article presents kind of small stepper motors investigations - testing of dynamic torque reaction for a single-step change of power supplying conditions. There are new measuring station and software specially configured to test very fast steppers.*

1. INTRODUCTION

Moderns drive systems very often works as accuators with use of a stepper motor. When they work with a feedback loop generally they use position or velocity signal as a moderator. Disc type permanent magnet stepper motors with they very high angular acceleration when they works with relatively large mass moments of inertia generating oscillations on the output shaft [1] and can be not reliable source of position signal. Article presents possible to use instead of mentioned signal - dynamic value of torque.

2. COMPUTERISED MEASURING STATION

As a test motor *escap® P 532-258 004* was used, it is disc type permanent magnet stepper motor. Because it characterising itself with a very high angular acceleration value (up to 170000 rd/s^2)[2] it was necessary to create special test station proper to be used in such conditions. It was developed under experiences and knowledge achieved during creating test rigs for automated detection of dynamic characteristics of stepper motors [3,4].

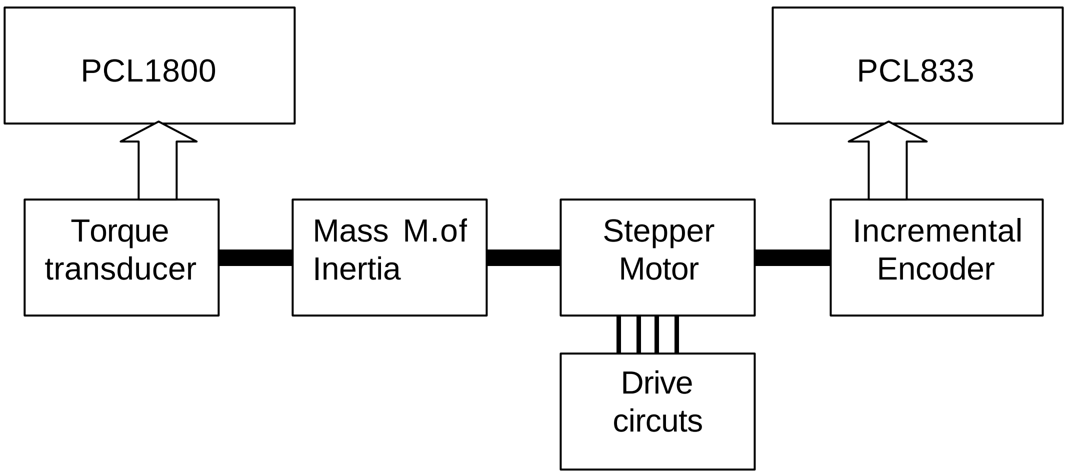

Fig. 1 Structure of the test rig (one of used configuration showed, motor shaft integrated incremental *HP* encoder used to determine shaft position)

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To be able to record such fast changes of values, two fast converters cards was used. First *Advantech® PCL1800* works as analogue to digital converter with the maximum sampling frequency at 330 kHz. Second one is *PCL833* fast digital counter, capable to count up to 4 MHz input frequency. Other components of measuring station are torque–meters, incremental encoders and motor's drive systems. I used two types of torque transducer. First one is the rotary torque-meter *OPM* developed and constructed in Institute of Micromechanics and Photonics WUT (*IMiF PW*), here used, with blocking on one end of its shaft, as stationary one. Second one is torque transducer based on piezoelectric force sensor made by *Kiestler* metering reaction on stator housing. Signals from both kinds of torque meters are measured by *PCL1800* card and transferred to computer memory. To determine shaft's angular position two types of incremental encoder were applied. Usage of one was very obvious it is originally mounted to motor *HP HEDS5500* with 500 lines on code wheel. Second one is one from *PK* series, it is also, as *OPM*, own construction of *IMiF PW*. *PK2000* used in test rig has 2000 lines on code wheel and as all *PK* encoders can generate 2 MHz position signal what means that it can work with ca 6800 rd/s angular velocity. To recalculate position and detect direction of rotation fast digital counter *PCL833* was used.

Presenting test station it can not be missed to write down little word about drive circuits used to supply tested motor. Used in experiment stepper has its own dedicated drive circuits *escap® EDI-201*. It is microprocessor controlled circuit able to supply motor with full, half, $^{1}/_{10}$ and $^{1}/_{32}$ step mode, also able to use during motor's work current busting algorithm to reduce transient states in coils while they are switched. Other drive circuit used in experiment was transistor switched circuit with current supply.

3. CHANGES OF DYNAMIC TORQUE AS THE RESULTS OF A SINGLE-STEP FUNCTION

Tests I have was as followed stepper was junketed to a one of three different fly-wheels what was the simulation of a real mechanism powered by a stepper. I was recording changes of value of dynamic torque on the motor shaft during switching on and off coils. Motor was driven in full step and half step mode what means that one coil was switched off while the other was switched on, or one was switched on while other one was continuously powered. Also I have manage the test when motor was powered to one coil only what is equal to beginning of work.

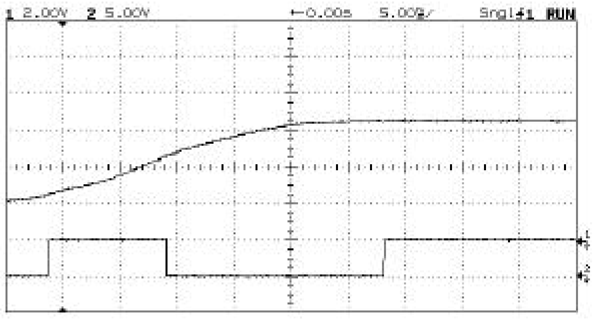

Fig. 2 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500* (1 A constant current power supplying, beginning of work, flywheel - 1300 gcm^2)

Figure 2 presents most ideal situation, motor starts smoothly to the first step, this effect was created by presence of relatively big flywheel and absence of a self inducting currents in coils, motor was stopped and without power supplying. As I mention it is ideal situation but flywheel's (whole test bed components are threaded her as one flywheel type load) mass moment of inertia was about 10^5 bigger then stepper rotor's one, this is rather unusual situation in mechanisms which are using small fast steppers.

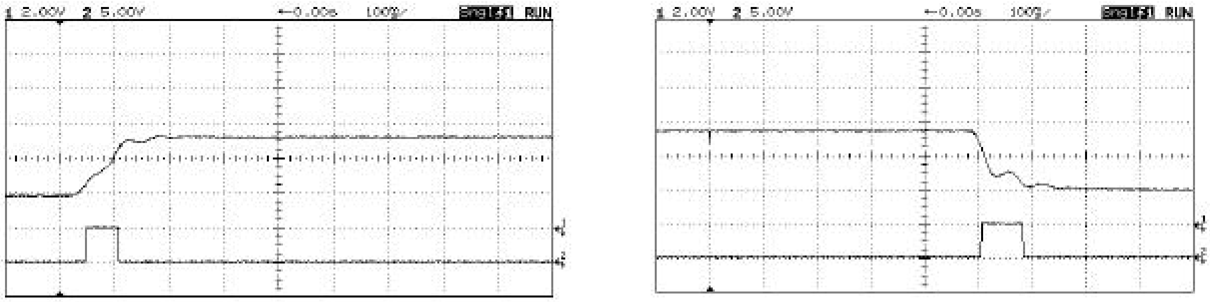

Fig. 3 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500*, left second coil turned on, right - off (0.5 A constant current power supplying, half step mode, flywheel - 1300 gcm^2)

As figure 3 shows when self-inducting currents are present even flywheel can not dump all oscillations. Next figure presents that changing the current to two times bigger does not change character of the oscillation (maximum overshot is still about 80-100% of static change value) only setting time has been lengthen.

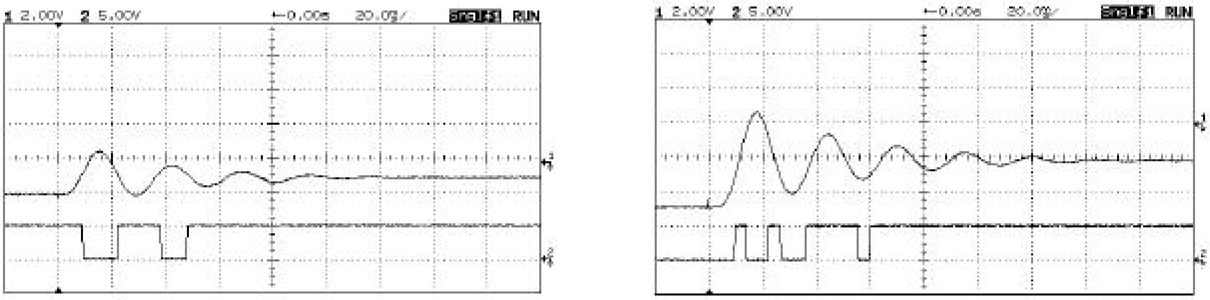

Fig. 4 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500*, power supply left 0.25 A, right 0.5 A constant current, (half step mode, flywheel - 480 gcm^2)

Fig. 5 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500*, left full step, right half step (power supply 0.25A constant current, flywheel - 96 gcm^2)

Figure 5 presents comparison between changes of a torque value with same load conditions and same current value but switched in different modes. Right picture shows a full step mode, means one coil was switched off and seconds one was turned on, left – half step mode, second coil was powered on while first was constantly powered. As it can be seen in full step torque rising time is slightly longer but overshot is radically lower.

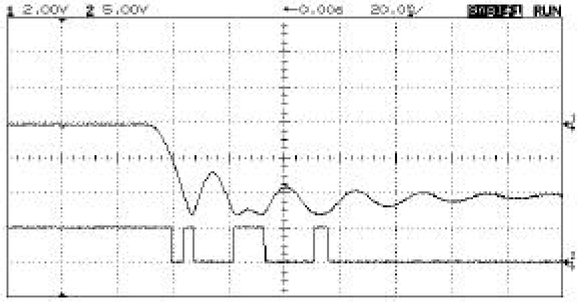

Fig. 6 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500*, (power supply 1 A constant current, half step mode, flywheel - 480 gcm^2)

Figure 6 presents situation when currents change so rapidly that the rotor during changing his position was "rebounded" by the electromagnetic forces from the next part of stator thooting. It is represented by a „sharp" end of first wave and characterising reflection at the bottom of a second one. Figure 7 shows another phenomenon that can appear during switching off one of coils. In the beginning torque value rises, it is another possible result of self-inducting currents, they are trying not to allying to change of rotor position. This effect is short time ones but in some circumstance can has a meaning.

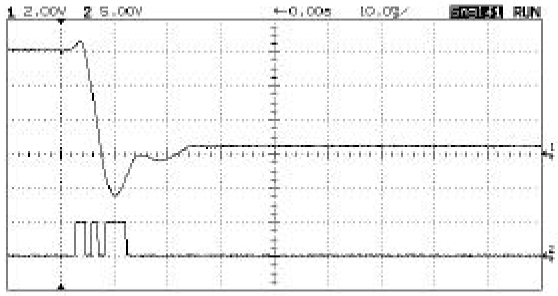

Fig. 7 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500*, (power supply 0.5 A constant current, half step mode, flywheel - 96 gcm^2)

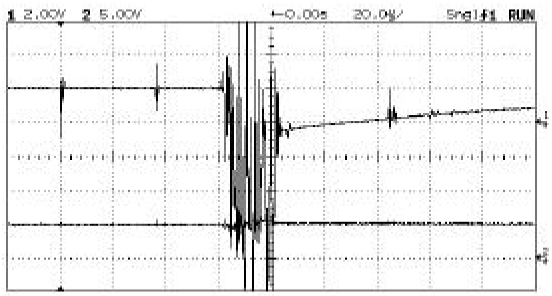

Fig. 8 Experiment results upper curve - torque changes taken from *OPM*, lower - position signal from *HP HEDS5500*, (power supply 1 A constant current, half step mode, flywheel - 96 gcm^2)

The last picture (Fig.8) it is a close up to the first 20 microseconds of a situation showed on figure 7. We can see how dramatically transient state passing, please remember that the motor load is about one hundred times bigger than mass moment of inertia of motor's shaft which is 1.2 gcm^2. When the load will be smaller, torque value settling time can be similar to position settling what can be a reason of mechanical oscillations or problems with start with a full nominal torque, undesirable in for example positioning mechanisms.

4. CONCLUSIONS

Presented experiments results showing effects of development and first usage of new test stand. They are part of works, about stepper motor dynamic behaviour and their characteristics, carried out by Institute of Micromechanics and Photonics WUT. Computerised test bed allows to record measured values during number of examinations and help to properly judge nature of observed phenomena. Following works carried by me personally are also parts of my prepared PhD thesis. Knowing of that how torque during single-step response change especially with the knowledge how shaft position simultaneously changes could be useful in mechatronic devices constructing and developing. I plan to test another new "intelligent" drive circuit and if it will be technically possible to test disk type stepper with load similar to they own mass moment of inertia, what depends on development of new light weight equipment.

5. REFERENCES

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