Bohumil SKALA

THE CALIBRATION AND OPERATIONAL EXPERIENCE WITH THE IMPROVED DYNAMOMETER

ABSTRACT *The torque measurement with the help of torsional torque transducers has the impact on the torsional stiffness of the machine-unit. The solution is to use the dynamometer, however the dynamometer is not suitable for fast transient phenomena. Due to this fact we have developed, design and constructed a special dynamometer, which has both advantages: zero influence to stiffness and being suitable for transients phenomena.*

This paper presents the main construction and possibilities of utilization and further it describes its behavior. The calibration and first experiences are also mentioned.

Keywords: *testing electrical machines, dynamometers, calibration*

Bohumil SKALA, Ph.D.

e-mail: skalab@kev.zcu.cz

Faculty of Electrical Engineering,
Dept. of Electromechanic and Power Electronics,
University of West Bohemia in Pilsen,
Univerzitni 8 306 14 Pilsen, CZECH REPUBLIC
tel. +420 377 634 473, fax: +420 377 634 473,

1. INTRODUCTION

As the heart of the dynamometer the standard asynchronous machine of the Elektrim Motor Company is used. This machine was produced with the both free ends of shaft and each of them has increased the length. This increased length is necessary for two new additional end-shields with bearing. The stator can swing around thanks to these additional bearings.

The starting position is held by two wound springs. These springs have the stiffness which holds the run-up of the machine under nominal voltage.

Some electrical machines have the non-constant torque and speed during one mechanical revolution. Stepping motors, switching reluctance machines or synchronous machine waving on the network may serve as examples.

Also in industry there are many applications where the torque is variable during one mechanical revolution. Typical examples are the starter for combustion engine, piston compressor powered by electric motor, etc.

2. DISADVANTAGES OF THE TYPICAL DYNAMOMETER

The main disadvantage follows from the following analysis. Let us assume that the rotor of the moment of inertia I [kg.m^2] has the angular acceleration $\frac{d\omega}{dt}$. Then the following relation must be valid:

$$I\frac{d\omega}{dt} = T_i - T_l - T_Z \tag{1}$$

Due to the fact that the stator parts are at rest, the following equation must be valid simultaneously

$$T_R + T_l - T_i = 0 \tag{2}$$

By the combination of both equations (2) and (3) we obtain

$$T_Z = T_R - I\frac{d\omega}{dt} \tag{3}$$

It follows from the last equation (3) that during the acceleration or deceleration we measure the torque with some systematic error. This error can be corrected by the rotor acceleration measurement and by the calculation of the equation element $I\frac{d\omega}{dt}$. On the other hand the advantage is that the bearings friction has no effect.

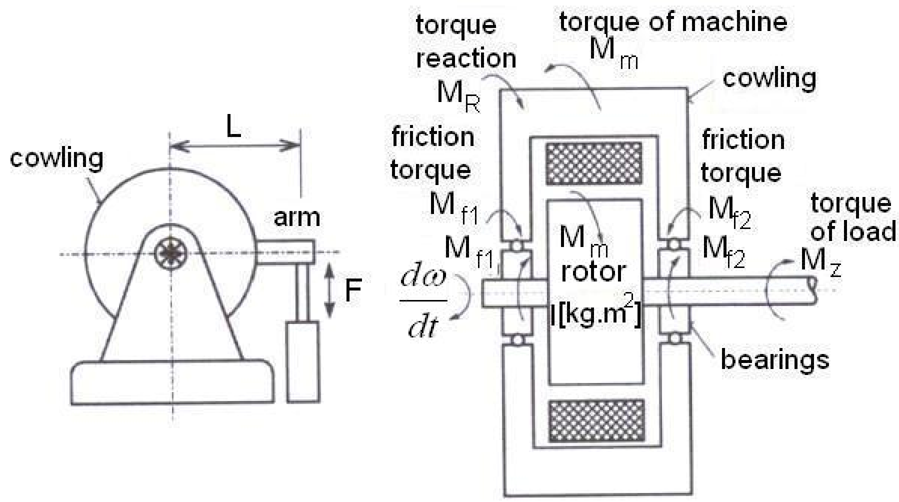

Fig. 1. Typical dynamometer

A typical rotary dynamometer can be seen in Fig. 1. This machine could be a DC machine or an asynchronous machine supplied via frequency converter. The force measurement device could be made not only of a spring but also of a piezoelectric sensor or any other press or force sensor, etc.

The dynamometer measures the reaction forces of the rotor. This reaction affects the stator and, in ideal case, this is equal to the action on the rotor. Due to this fact the dynamometer is equipped with very precise bearings. Usually the bearings have a spinning ring of rolling elements even if the dynamometer rotor is at rest. Only in this way the torque is minimized which is needed to put the rotor from the rest state in motion.

The force F on the arm of length L is measured by the force sensor. Reaction torque of the stator is given by the relation

$$T_R = LF_R \tag{4}$$

3. THE REASONS FOR THE DESIGN OF A NEW DYNAMOMETER

The typical dynamometer is not suitable for transient phenomena measurement even when the force sensor is fast responding and modern digital data acquisition is provided.

If we required the transient phenomena evaluation, another way is possible. We can use for example a torsion torque sensor. This method unfortunately has another disadvantage – we change the torsion stiffness and the behavior during transient phenomena as well.

As a consequence of these reasons we decided to construct a new dynamometer, which would be suitable for fast transient phenomena measurement.

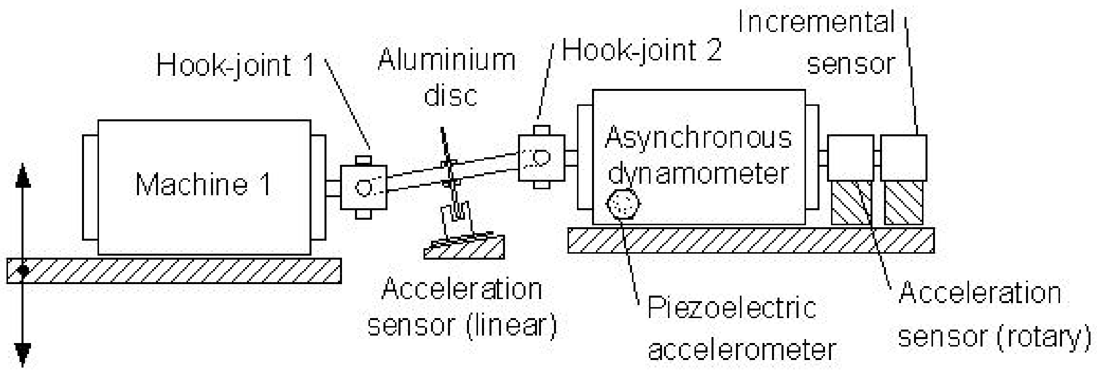

Fig. 2. The sensors placing on the dynamometer (with exception of voltage and current sensors)

4. THE DESIGN OF THE NEW DYNAMOMETER

As a machine the standard asynchronous machine of a power 4 kW was used. The stator of this machine can swing around up to 30 deg thanks to two additional bearings. The reaction is held by two springs. The stator is equipped with a piezoelectric accelerometer. The rotor is equipped with a contactless rotary accelerometer and in addition with an incremental speed sensor.

Consequently, we can evaluate the acceleration of the rotor $\frac{d\omega}{dt}$ and stator $\frac{d\omega_S}{dt}$ as well. Moment of inertia of the rotor I [kg.m^2] can be easily found in the machine producer catalogue or determined by measurement [1]. The stator moment of inertia I_S we have to measure before dynamometer mounting.

5. DETERMINATION OF MECHANICAL PARAMETERS

The moment of inertia was also determined by special measurement. The trifilar torsion pendulum method was used.

When we want to improve the classical dynamometer, the precision must be very high. Due to this fact we provide measurement several times with various angles displacement and length of hanging as well. All experiments were measured and evaluated by the computer.

We measure not only the rotor but even the stator moment of inertia. The moment of inertia of the stator included the terminal box, foots and all other accessories (lifting eye).

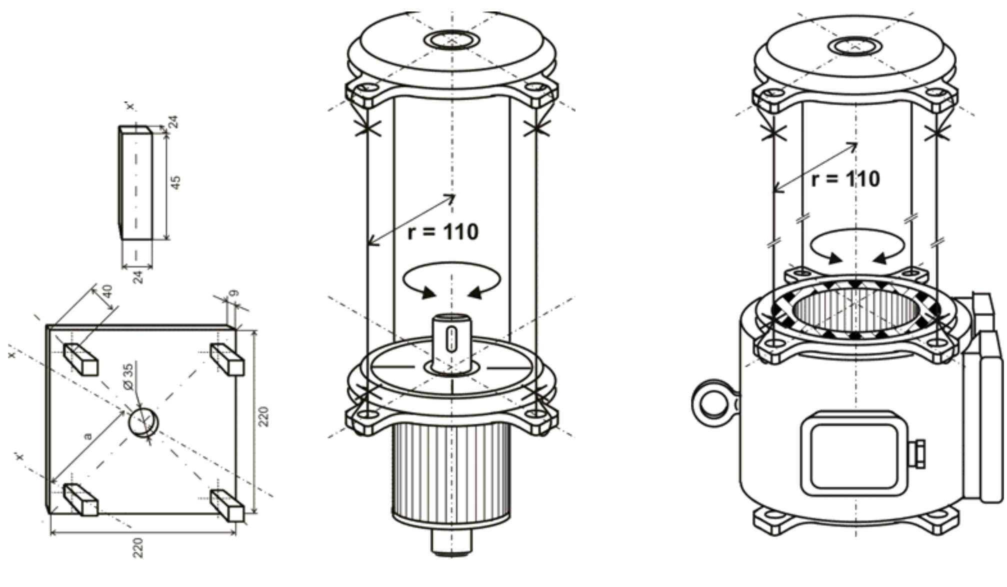

Fig. 3. The determination of moment of inertia of various parts of the machine (dynamometer)

6. DETERMINATION OF ELECTRICAL PARAMETERS

The determination of the equivalent circuit parameters was based on no-load test and short circuit test. The precision of this determination was verified with the help of resistivity measurement by the Ohms method.

7. CALIBRATION OF THE DYNAMOMETER

The dynamometer was calibrated in two levels. First level was static calibration.

a) b)

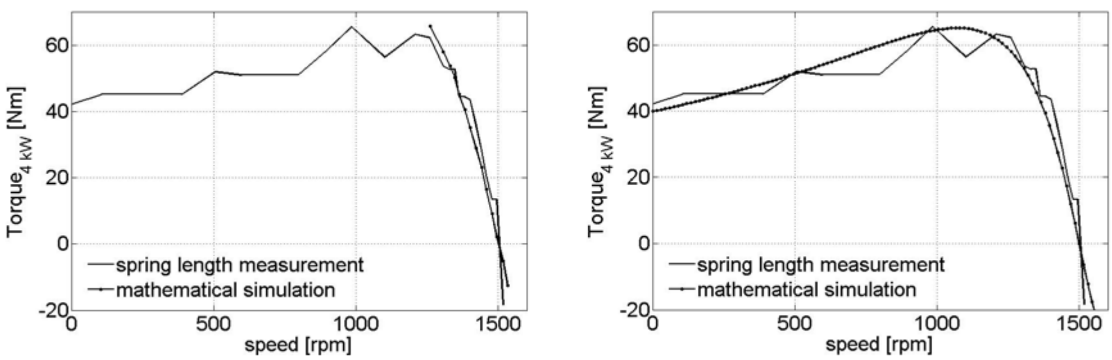

Fig. 4. The comparation of various principles of the torque determination.
(a) Due to the overloading of the machine the comparation was performed only in the working part of the torque characteristic.(b) The comparation of the measurement and simulation of the static torque characteristic.

With the help of a force sensor the spring forces on the well known length of the arm were measured. In the second level we compared the transient response with the simulation results.

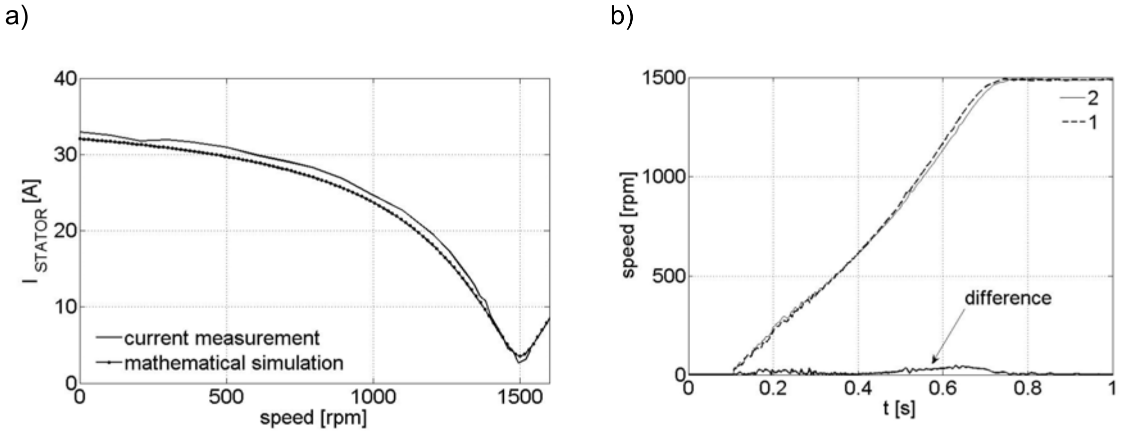

Fig. 5.
(a) The comparation of the measurement and simulation of the stator current characteristic. (b) Comparison of the integration of acceleration signal - rotor speed error. Detent stator (1) versus stator swinging neglected (2).

8. NOTIFICATION

I_S… moment of inertia of the stator
I_R… moment of inertia of the rotor
m… mass
T_i… internal torque
T_l… torque of bearings
T_Z… torque of load
T_R… torque of reaction
T… time of period of oscillation
t … time
x, y… displacement
ω… angular speed of the rotor
ω_S… angular speed of the stator

9. REMARKS AND CONCLUSION

The asynchronous dynamometer is supplied with a frequency converter. In this way it should work in the motor as well as the generator mode. The mechanical load will be connected through the cardan shaft.

LITERATURE

1. Hrabovcová, V., Rafajdus, P., Franko, M., Hudák, P.: Measurement and models of electrical machines. University of Zilina, EDIS 2004

2. Zehnula, K.: Sensors of nonelectric magnitudes. SNTL Prague 1983

2. Daďo, S., Kreidl, M.: Sensors and measurement circuits. ČVUT Prague 1999

Acknowledgement
This work has been supported by the project no. FI-IM2/071.

Manuscript submitted 14.11.2006
Reviewed by Jarosław Zadrożny

WZORCOWANIE I DOŚWIADCZENIA
EKSPLOATACYJNE
UDOSKONALONEGO DYNAMOMETRU

B. SKALA

STRESZCZENIE *Pomiary momentu obrotowego przy pomocy przekształtnika momentu skrętnego wpływają na sztywność maszyny na skręcanie. Rozwiązaniem jest użycie dynamometru, ale dynamometr nie jest odpowiedni dla wszystkich przebiegów nieustalonych. Dlatego opracowaliśmy i zbudowaliśmy specjalny dynamometr, który ma duże zalety: zero wpływu na sztywność i przydatność do zjawisk nieustalonych.*

Artykuł przedstawia budowę, możliwości użycia i zachowanie się dynamometru. Jak również jego wzorcowanie i pierwsze doświadczenia eksploatacyjne.