Research stand with electrodynamic brake

Stanowisko badawcze z hamulcem elektrodynamicznym

KRZYSZTOF NALEPA
WOJCIECH MIĄSKOWSKI
MARZENA WILAMOWSKA-KORSAK
PIOTR PUCHOWSKI *

The article presents the design and characteristics of the eddy current electrodynamic brake used in the system working with an asynchronous motor. The construction of the stand allows the determination of the characteristics of electric motors in combination with the regulated mechanical load in the form of an electrodynamic brake. The presented electrodynamic brake allows precise adjustment of the torque loaded on the tested motor. It allows the load up to 10 Nm at speeds ranging from 100 to 1500 rpm.
KEYWORDS: eddy current, electrodynamic brake

Eddy current brakes fulfill a function similar to the friction brakes (which are most common), but to produce braking force they use the physical phenomena occurring in the conductor moving in the electromagnetic field. The electromagnetic field induces a voltage in each metal element that moves perpendicular to the line of the field. The induced voltage is the source of the vortex currents, producing an electromagnetic field that counteracts the source field and thus produces a force whose one component is opposed to the direction of travel of the braked element [1, 2].

Design and construction of the brake

A braking system belonging to the group of wheel type brakes was mounted on the stand. The brake forces the tested motor to the torque it produces. The functional premise was to develop and build a stand that would allow testing of drive systems (wind motors) and low power generators. It was necessary to develop an electrodynamic brake and to examine its actual parameters and scope of application for the first purpose.

The measuring stand consists of the following units:
- eddy current brake with adjustable power supply,
- power unit consisting of an engine and a power unit,
- measuring devices,
- basics of the stand.

The view of the complete stand is shown in fig. 1.

The brake work assembly is made up of modules consisting of two units:
- power unit, including caged asynchronous motor powered by the inverter;
- brake assembly incorporating an electrodynamic brake and adjustable DC power supply.

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* Dr inż. Krzysztof Nalepa (nalepka@uwm.edu.pl), dr inż. Wojciech Miąskowski (wojmek@uwm.edu.pl), dr inż. Marzena Wilamowska-Korsak (wilam@uwm.edu.pl), dr inż. Piotr Puchowski (piotr581@wp.pl) – Wydział Nauk Technicznych Uniwersytetu Warmińsko-Mazurskiego

The modular construction of the stand ensures its versatility. The stand can be used to test:
- propulsion systems – after replacement of the propulsion system shown here, tested propulsion system; the brake serves to load the mechanical drive under test;
- low-speed generators of electricity – the electrodynamic brake is removed, and in its place is assembled a circular electricity generator; drive system with cage motor and inverter provides torque with variable rotational speed control.
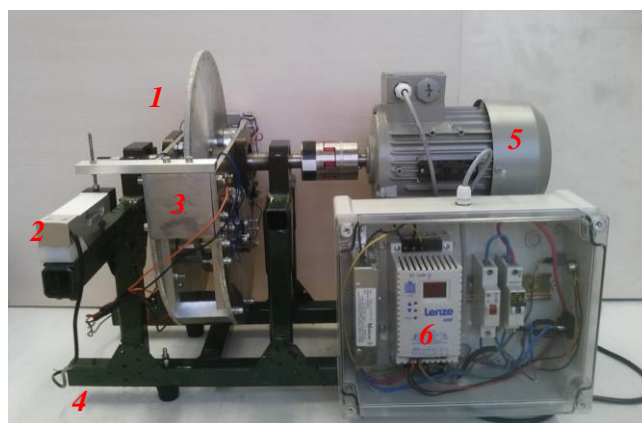

Fig. 1. View of the complete stand for testing the eddy current brake: *1* – brake disc, *2* – load cell, *3* – yoke with electromagnets, *4* – stand, *5* – motor, *6* – inverter

The system was manufactured by Siemens, a star-linked three-phase asynchronous 1LA7083-4AA10-Z engine with a rated power of 0.75 kW at a rotational speed of 1395 rpm and a rated torque of 5.1 Nm. The drive engine is compatible with the Lenze smd inverter, providing smooth control over the entire engine speed range.

The braked element, made in the form of an aluminum homogeneous disc, is provided with a shaft mounted in the housing. On the sides, 12 ITS-MS-5030 electromagnets, attached to the aluminum side covers, were placed at the bottom of the element. There are six electromagnets on each side of the dial. Side covers are the elements of the brake frame with which the arm extends into the strain gauge.

Two main parameters were tested on the stand: the braking torque observed as the force acting on the fixed arm and the rotational speed.

The first parameter was measured using a strain gauge type BTENS-N1-020.

The arm attached to the brake housing directly affected the strain gauge beam. The signal from the beam was sent to the ADT1-U measuring module from Wobit, which

was connected to a computer with the MDT100T-PC monitoring program installed.

The rotational speed was measured with a Sentry ST723 contact-free tachometer.

The base was made as a welded construction of 30 × 30 mm steel profiles and a 3 mm wall thickness. Four support elements were used, resembling the inverted letter "U". The lower two are the backrest for the engine and two higher – for the brake. The carriers were welded to the "H"-like base, and the base was set on four vibration-isolating feet to provide stable and safe operation during the test.

The profiles were made of structural steel S235359 with the parameters given in the Table I.

TABLE I. Parameters of structural steel S235359

Elasticity coefficient, N/m^2	2.1 e+011
Poisson's ratio	0.28
Shear stress ratio, N/m^2	7.9 e+010
Specific weight, kg/m^3	7700
Tensile strength, N/m^2	723 825 600
Tensile strength, N/m^2	723 825 600
Plasticity limit, N/m^2	620 422 000
Coefficient of thermal expansion, 1/K	1.3 e–005

Base strength analysis

Strength analyzes have been carried out, taking into account the static loads and workloads of the workstation, to check the structural durability and to determine whether the entire system is safe for the user during operation. Solidworks with Simulation was used for analysis.

Analysis of the statically loaded construction is to check the deformation of the base caused by the weight of the brake and the engine. The analysis was divided into four more detailed studies. The first three strengths were 250 N and equaled the sum of the thrust forces exerted by all attached elements. In the fourth study, there was simultaneous interaction of identical loads along all three axes. The sum of the force components was 250 N. At the same time, a longer and shorter support was applied to each test. This paper presents the results of the combined force interaction (fig. 2 and fig. 3).

The strength analysis of load cases resulting from the work of the station allowed us to check the strength of the structure for maximum loads caused by the influence of the braking force on the arm of the load cell. The maximum torque that a motor can produce is 15 Nm. Based on calculations made in the Solidworks environment, this torque can generate at the end of the arm a maximum thrust force of 91 N. Due to the versatility of the post, the beam loading force has been increased three times – up to 273 N. As a result, the stress distribution in the components and the value movements. In each study, gravity was also taken into account. Finite element mesh parameters used in the analyzes are given in Table II.

TABLE II. Finite element mesh parameters

Grid type		Solid grid
Used grid generator		Standard grid
Automatic transition		Disabled
Include automatic grid loops		Disabled
Jacobian points		4 poinst
Element size, mm		9.82939
Tolerance, mm		0.49147
Grid quality		High
Total number of nodes		63 096
Total number of elements		31 916
Maximum aspect ratio		15.082
Percentage of elements with a shape factor of	< 3	35.3
	> 10	0.0815

The maximum stress in the modeled base was 6.8223 MPa and the maximum displacement was 0.0221 mm (fig. 2). In turn, the maximum stress in the beam of the strain gauge beam was 22.63 MPa and its maximum displacement was 0.079 mm.

In no case was the yield strength exceeded, i.e. 620.42 MPa. The maximum value in static tests was 14.38 MPa, while in dynamic tests – 22.63 MPa. The largest displacement was 0.079 mm (dynamic load test). The displacement values do not exceed a pre-set value of 0.5 mm.
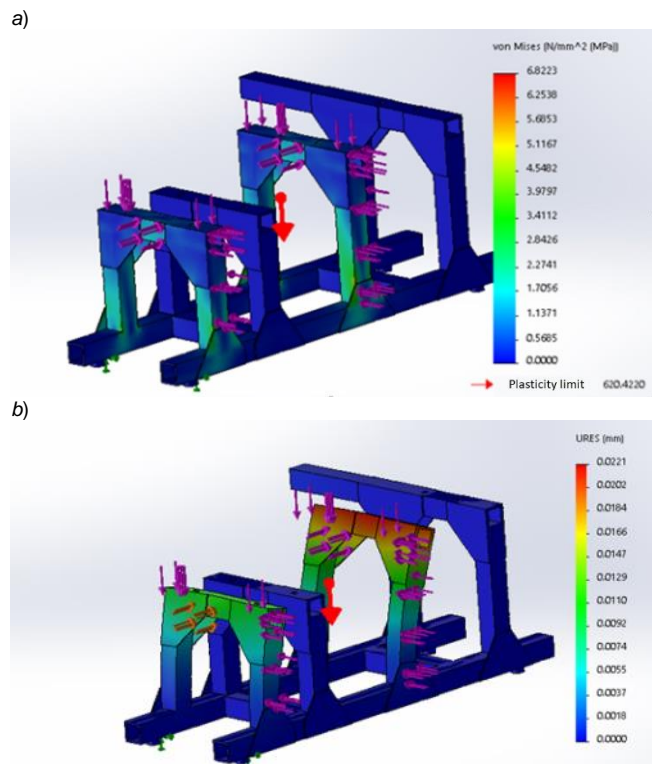
a)

b)

Fig. 2. Sum values of stresses (*a*) and displacements (*b*) of the base elements
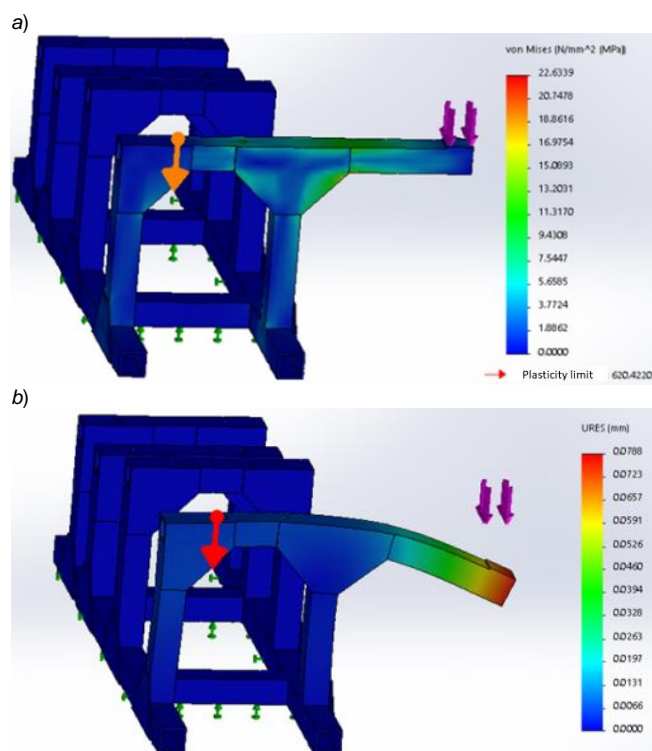
a)

b)

Fig. 3. Sum values of stresses (*a*) and displacements (*b*) of strain gauge beam

Examination of the eddy current brake

The tests for ten inverter settings for the asynchronous motor were performed: 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 Hz. They are synchronous speeds: 150, 300, 450, 600, 750, 900, 1050, 1200, 1350 and 1500 rpm. The tests were carried out successively for a fixed value of motor current. During testing, the frequency value of the inverter was set and the brake voltage applied to the brake solenoids was changed from 0 to 20 V, thus causing the mechanical load on the motor. The force value was read using a strain gauge and the speed value was measured using a tachometer.

The results of the brake test – the family of brake characteristics for the adjustable supply current frequencies – are shown in fig. 4. Fig. 5 shows the dependence of the maximum torque obtained with the supply voltage of 20 V.
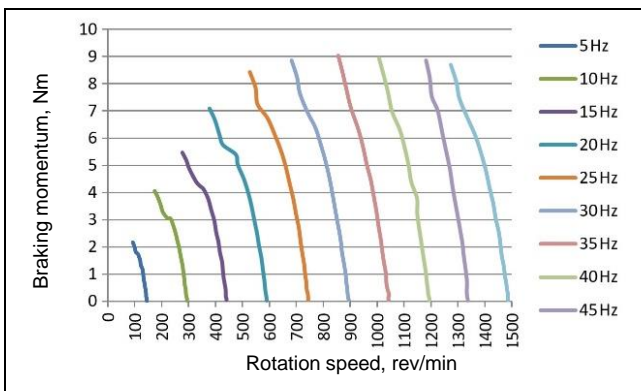

Fig. 4. Brake torque characteristic produced when supplying the brake with voltage from 0 to 20 V at various settings of motor inverter (5÷50 Hz)
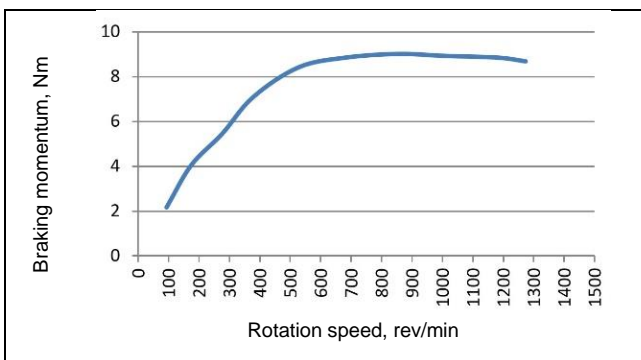

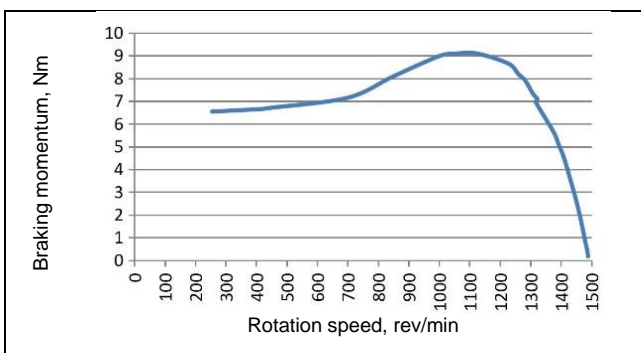Fig. 5. Maximum braking torque generated during brake operation at 20 V supply voltage

Fig. 6. Torque characteristics generated by the motor, obtained for the application of an electrodynamic brake

One of the functionalities of the presented stand is the possibility of testing propulsion systems. An engine with an electrodynamic brake was tested. The sample characteristics of the test torque of the Siemens 1LA7083-4AA10-Z engine as a function of the rotational speed are shown in fig. 6. The tests were performed for a set frequency of 50 Hz (synchronous speed 1500 rpm) – the motor was loaded until a load torque of equal critical value, followed by a decrease in the driving torque generated by the engine.

Conclusions

The test stand presented in this paper has been designed and built to test drive systems in the form of wind turbine models that are to be used to convert wind energy into quasi-autonomous lighting or signaling points (electrodynamic brake module), intended for lighting or signaling points (stand with drive module, suitable for testing generators).

The presented characteristics illustrate the range of applicability of the electrodynamic brake. It allows precise adjustment of the torque loaded on the tested engine and provides a load of up to 10 Nm at speeds ranging from 100 to 1500 rpm.

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