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RESULTS FROM LABORATORY TESTS OF NEW ELECTRIC BRAKE PROTOTYPE

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Abstract

The main idea of this article was to compare the results of new design electric brake to the older version of hydraulic brake in laboratory tests. The energy of braking should be very similar due to the same mass of the airplane. That is why the laboratory tests of both brakes were took place in the same stand. Of course, the parameters were similar but not at all. The main idea was to create the solution, which could be used in vehicle like airplane. The electric brakes could replace traditional hydraulic brake solution. The results could be interesting for every researcher who is interested in brakes. Other important idea of this article was to describe the tests of new electric brake prototype. The purpose of the tests was to check designing of electric brakes. The electric brake prototype should ensure sufficient efficiency, safety, reliability and durability during braking, which is required in certification processes and is particularly important when researching innovative solutions. It was really important to verify the design and check the parameters. Of course, there is really important to remember that in every new type of the prototype solutions there are many pros and cons, which are typical only for considered design. Nowadays every electric brake design is different because there is a lot of new concept.

Keywords: *laboratory test, electric brake, braking process*

1. Introduction

The electric brake has been designed since the idea, conception to the last prototype phase. After the assembly phase, the electric brake was mounted on the test stand and the tests were conducted. The purpose of the tests was to check designing of electric brakes. The electric brake prototype should ensure sufficient efficiency, safety, reliability and durability during braking, which are required in certification processes and this is particularly important when researching innovative solutions. It was really important to verify the design and check the parameters [2].

In our examples, there were tested two brakes electric and hydraulic. Both solutions could be used in the same type of airplane. The hydraulic brake was tested in the past.

2. Parameters and results of electric brake tests

Firstly a series of initial braking was performed. The initial braking tests were carried out to optimize the surface area of interaction of friction linings and brake disc. The frictional contact surface area by lapping was as close as possible to the geometric maximum, by levelling the shape errors (waviness, non-parallelism etc.) and excessive roughness, through which frictional cooperation takes place only on a part of the surface – roughness peaks [4].

The tests were started with the small treadmill energy. Firstly the tests were started carefully due to designing functionality was tested. The full scale designing correctness of all parts was verify and the idea of designing this solution of electric brake was checked. Then the correct parameters were selected and set. There was possibility to change the braking characteristics for example to increase efficiency or lifespan of linings. Later the energy increased even to the take-off energy, which is the highest energy for brakes in airplanes after landing.

Data used for trials:
P = 349 daN – static load of the wheel,
I_b = 588 kgm^2 – inertia of the treadmill,
p_{op} = 0.38 MPa – tire pressure,
m_s = 1117 kg – mass of the aircraft,
V_{so} = 113.3 km/h – stall speed,
E_h [J] – braking energy,
a_s [rpm/s] – acceleration of engine rotation,
a_p [rpm/s] – engine speed delay,
n [rpm] – speed of the treadmill,
t [s] – braking time,
T_{disc} [ºC] – brake disc temperature.

During the tests, the temperature was checked after the every trial by pyrometer. In different tests, the temperature of disc was changed because the energy of every test increased. The results are shown in Tab. 1 and 2.

Tab. 1. Results of tested electric brake

No.	P [daN]	I_b [kgm^2]	E_h [J]	a_s [rpm/s]	n [rpm]	t [s]	T_{disc} [ºC]	Comments
1	349	588		3000	29		27	
2	349	588		3000	22		27	
3	349	588		3000	44	3.5	30	
4	349	588	8632.62	3000	50	4	30	
5	349	588	8632.62	3000	55		37.5	Without reg.
6	349	588		3000	300			Free run
7	349	588		3000	300	850		Free run
8	349	588		3000	50	45		Free run
9	349	588		3000	50	46		Free run
10	349	588		3000	50	46		Free run
11	349	588	19423.40	3000	78	8	46	
12	349	588	34530.49	3000	104	8	62	
14	349	588	34530.49	3000	104	8	59.5	
15	349	588	53953.89	3000	130	10	60	
16	349	588	77693.61	3000	156	14	93	
17	349	588	105749.63	3000	182	14	112	
18	349	588	138121.96	3000	207	16	140	
19	349	588	174810.61	3000	233	16	144	
20	349	588	215815.57	3000	259	20	175	
21	349	588	276558.28	3000	294	20	212	Take off speed
22	349	588	34530.49	1000	104	8	50	
23	349	588	77693.61	1000	156	10	84.5	
24	349	588	138121.96	1000	207	14	131	
25	349	588	34530.49	5000	104	6	44.7	
26	349	588	77693.61	5000	156	8	75	
27	349	588	138121.96	5000	207	11	134.8	
28	349	588	174810.61	5000	233	14	167	
29	349	588	215815.57	5000	259	15	190	
30	349	588	276558.28	5000	294	17	270	Take off speed

Tab. 2. Results of tested electric brake with braking moment measurement

No.	P [daN]	I_b [kgm^2]	E_h [J]	a_s [rpm/s]	n [rpm]	t [s]	T_{disc} [ºC]	$M_{h\ max}$ [daNm]	Comments
31	349	588	34530	5000	104	7	50	200	
32	349	588	53953	5000	130	8	87.5	200	
33	349	588	77693	5000	156	8	91.6	200	
34	349	588	105749	5000	182	10	130.5	190	
35	349	588	105794	5000	182	10	135.7	200	
36	349	588	138121	5000	207	12	156	200	
37	349	588	174810	5000	233	12	171	210	
38	349	588	215815	5000	259	15	212	220	
39	349	588	276558	5000	300	16	270	220	Take off speed
40	349	588	34530	3000	104	6	55	230	
41	349	588	53953	3000	130	7	76	230	
42	349	588	77693	3000	156	9	94.7	210	
43	349	588	34530	6000	104	6	60	240	
44	349	588	53953	6000	130	8	79	240	
45	349	588	77693	6000	156	9	99	230	
46	349	588	34530	8000	104	5	65	240	
47	349	588	53953	8000	130	7	87	230	
48	349	588	77693	8000	156	9	92	220	
49	349	588	105749	8000	182	-	105	200	Multiple braking
50	349	294	34530	8000	147	2	32	210	
51	349	294	53953	5000	183	4	42	220	
52	349	294	77693	5000	220	5	75	200	

In the Fig. 1 there was shown the stand in laboratory. The stand parts and equipment was assembled based on the 3D model of full prototype, which was shown in Fig. 2.

Fig. 1. View of the brake on stand

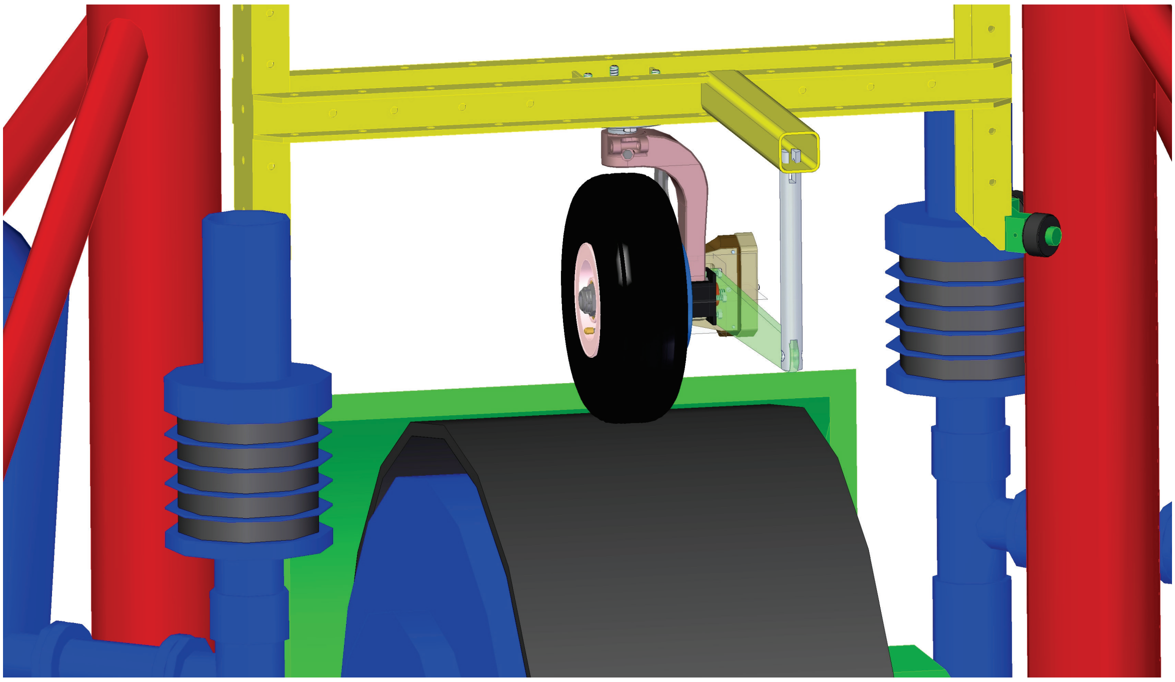

Fig. 2. View of the brake on stand – 3D model

The all fifty-two results from tests of electric brake were shown in these tables. Since thirty-one test, the moment of braking has been measured.

The typical graph from tests was shown in Fig. 3. In this example, the trial No. 29 (Tab. 1) was taken into account to show how it was looked. The speed of treadmill (red and navy blue colour on graph – two different sensors were used to ensure the results were good enough) decreased from about 259 rpm to 0 rpm. The time of braking was about 15 s.

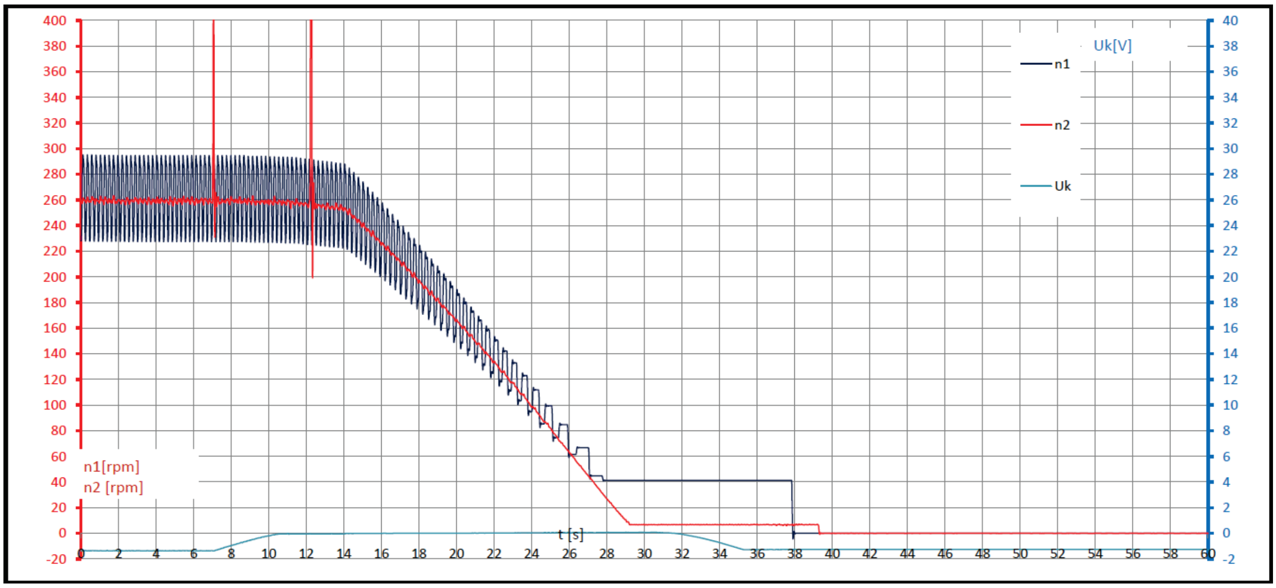

Fig. 3. Graph from brake test on Młot 3T stand for n = 259 rpm

In the second example, the trial No. 37 (Tab. 2) was taken into account to show how it was looked. The speed of treadmill (red and navy blue colour on graph – two different sensors were used to ensure the results were good enough) decreased from about 233 rpm to 0 rpm. The time of braking was about 12 s. The braking moment (green line on graph) was about 210 daNm. The braking moment on graph was only during braking process. This was shown in Fig. 4.

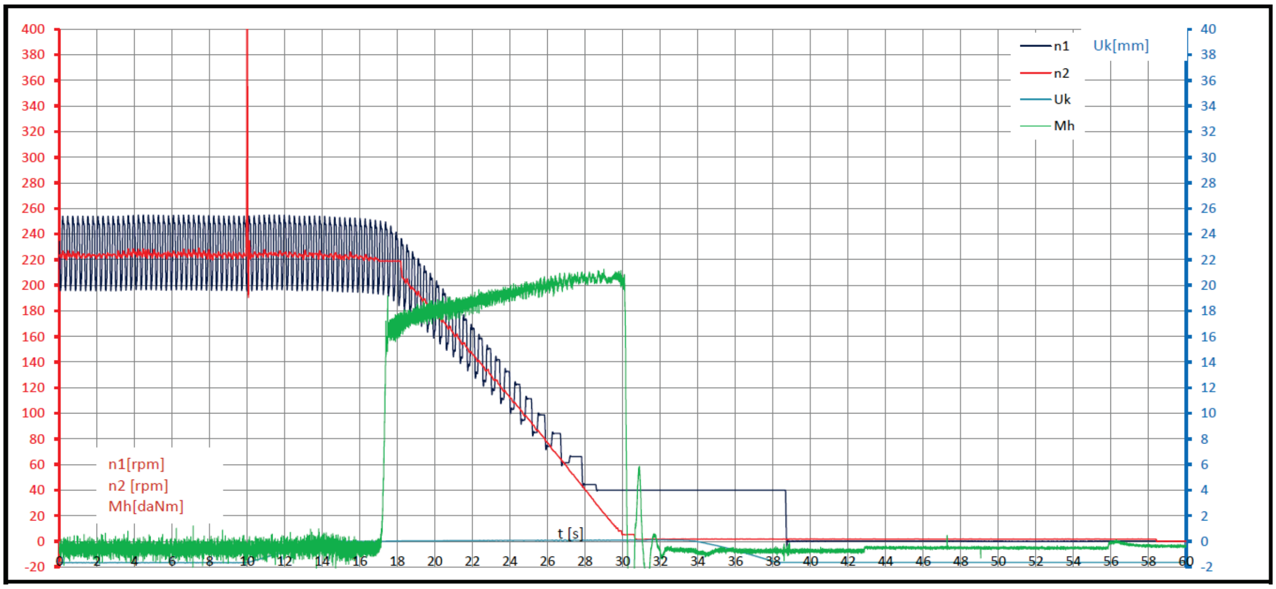

Fig. 4. Graph from brake test on Młot 3T stand for n = 233 rpm

The measurement of the braking moment gave the answer of the piston force in brake, which were used to braking on the linings. The calculated force was nearly the same like from tests. The special equipment was designed to measure the braking moment. The wheel with brake assembly was redesigned only for measure the moment of braking (Fig. 1).

3. Parameters and results of hydraulic brake test

In the past the tests of hydraulic brake was took place to the I-23 airplane. The parameters of the tests:

P = 349 daN (328 daN for M = 1050 kg) – static load of the wheel,
I_b = 294 kgm^2 – inertia of the treadmill,
V_p = 113.3 km/h = 31.47 m/s (e.g. = 430 rpm) – stall speed,
p_h = 2.94, 3.92, 4.91 MPa – braking pressure,
p_{op} = 0.38 MPa – tire pressure,
M = 1117 kg – mass,
n [rpm] – speed of the treadmill,
t [s] – braking time,
T_{disc} [ºC] – brake disc temperature.

Tab. 3. Results of tested hydraulic brake

No.	Energy of braking E_h [J]	Braking pressure p_h [MPa]	Braking time t [s]	Temperature of disc brake T [ºC]	n [rpm]
1	276597	2.94	10	417	113-430
2	276597	2.94	10.2	414	113-430
3	276597	2.94	10.1	434	113-430
4	276597	3.92	9	390	113-430
5	276597	3.92	8.5	433	113-430
6	276597	3.92	8	440	113-430
7	276597	4.91	7.4	415	113-430
8	276597	4.91	7.1	429	113-430
9	276597	4.91	7	430	113-430

The tests were carried out with the highest possible energy. This energy was calculated for the airplanes energy after landing which take place during braking. The stand energy, which brake needed to stop was the same. The braking pressure was different which decreased the braking time and braking distance.

The braking time, which has influence to the braking distance, is nearly the same. The time of braking was 10 s in hydraulic brake and in electric brake; it was 16 s in the best test. The parameters were compared only for braking with maximal energy due to the tests were conducted only for this energy in hydraulic brake. The temperature of disc brake was higher in hydraulic brake.

The maximal force possibilities of the electric brake were not used due to complex of the tests and multiple issues, which the designers wanted to check. There was a possibility to create the braking characteristics by changing the electric brake parameters.

If the braking characteristics were change by increasing the motors brake parameters, the efficiency would have been better and the braking distance decreased.

4. Summary

The methods of the testing new prototype electric brake and hydraulic brake were the same. In the same laboratory stand were carried out all the tests. Final analysis of the electric brake system during the braking showed there was no very significant difference between both solutions. The results showed that there is possibility to use the electric brake in airplane with nearly the same efficiency as hydraulic brake. Nowadays where every hydraulic system in airplane is replaced by electric system, this option could be very useful and popular for designers.

The analysis of the electric brake showed that there is huge potential of controlling the braking characteristic and improve the efficiency to the needs.

All of the tests and analysis described in this article were performed in the Landing Gear Laboratory of Institute of Aviation in Warsaw.

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