# CONTRIBUTIONS TO THE DESIGN OF ELECTROMAGNETIC POWDER BRAKES

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**REZUMAT. Frâna electromagnetică cu pulbere (FEP) este un dispozitiv antidemaraj de transmisie a puterii, de design simplu, greutate redusă şi dimensiuni mici, bine adaptată la cerinţele din industria grea. Lucrarea prezintă o FEP, alternativă cu rotor de gabarit, de 200 Nm, viteza de 1000 / min, reprezentat simplificat în figura 1. Luând în considerare avantajele de utilizare a acestor dispozitive, s-a stabilit experimental că valoarea optimă a întrefierului de lucru este de 1,6 mm. Teoria FEP şi alte rezultate cu privire la proiectarea şi experimentarea lor sunt prezentate în [1,2 ... 5]**

**Cuvinte cheie:** frâna electromagnetică cu pulbere, pulbere feromagnetică, cuplu electromagnetic

**ABSTRACT. The electromagnetic powder brake is a disengage power transmission contra device, of simple design, low weight and small size, well adapted to the requirement of the heavyindustry. This study presents an electromagnetic powder brake, the alternative with rotor of mail weigh, 200 N.m, 1000 speed/min.. Taking into account the advantages of using thesedevices we found experimentally that the best field coil is the one of 1,6 mm.**

**Keywords:** electromagnetic powder brake, powdered magnetic materials, electromagnetic coupling

## 1. INTRODUCTION

Electromagnetic powder brakes (FEP) are the only devices that can provide a constant brake torque at any speed of rotation, in the field of their working. As a coupling device [5] FEP represents a modern version of the electric induction synchronous and asynchronous machine, with the particularity that the air gap is filled with ferromagnetic powder treated with a series of substances acting as separators.

The FEP is specially designed and built for tests stand equipment for trying the endurance of planetary gear units that can be successfully used in industrial applications. Such applications can be: maintaining constant the traction effort, implementation of fast stopping of some mechanisms that do not allow operation after disconnecting the motor drive or reaching a specific point limit, carrying out constant coupling from a printer, either the paper or of a weld electrode, the accurate position of some execution elements in an automatic system, the protection of some mechanical transmission components, etc.

## 2. THE DESIGN OF FEP AND CONSTRUCTION VERSIONS

In the absence of the excitation current, the FEP represents a normally open clutch with sliding which is controlled by the excitation coil. When the excitation current is developing and increases, the magnetic field lines are closing through rotor-stator air gap and increase the flux density in the working air gap that is filled with a ferromagnetic powder. The result of this phenomenon is the increase in the strength tangential to the periphery of the rotor and because the stator is blocked, the imposed braking torque occurs.

The main factor that conditions the braking torque, as in the case of the electromagnetic powder couplings [3, 5], is the specific effort of displacement whose value depends on the magnetic flux density in the air gap, the size of the air gap, the quality of the filling material and a number of constructive parameters.

For designing we used as starting parameters the nominal braking torque $M_n$ = 20 daNm at the nominal rotation speed $n_n$ = 1000 rot/min, taking as constructive variant one with massive rotor such as toothed wheel, with longitudinal section shown in Figure 1.The initisal parameters had the following values: a working air gap of $\delta$ = 1 mm, width of the rotor at the air gap level $b_\delta$ = 66 mm and the rotor diameter $D_m$ = 190 mm.

The specific effort of resistance to the displacement τ, can be determined by the relationship:

$$\tau = \frac{200 \cdot M_n}{\pi \cdot D_m^2 \cdot b_\delta^2 \cdot m} = 0{,}53\, daN / cm^2 \qquad (1)$$

where: m = 1 number of working air gaps; $M_n$ is expressed in daNm; $D_m$, $b_\delta$ in cm.

The peripheral speed of the rotor is given by the classical relation:

$$v = \frac{\pi \cdot D_m \cdot n_n}{60} = 9{,}94 \text{ m/s} \qquad (2)$$

Depending on the type of powder used (in the studied case was used the carbonyl iron powder with fine dispersed glass) one can determine the value of the magnetic induction in the air gap [2, 3]

$$B_\delta^\beta = \tau / k_p \cdot k_v \cdot k_0 = 0{,}664 \qquad (3)$$

where: $k_p$ – coefficient depending on the composition of ferromagnetic powder [2,3];

$k_v$ – speed coefficient which depends on the size and peripheral speed of the air gap [2,3,5];

$k_0$, β – coefficients that depend on the density of the filling material and the size of air gap.

From the calculations result: $B_\delta$ = 0,761 T,. We further used a rounded value of $B_\delta$ = 0,8 T

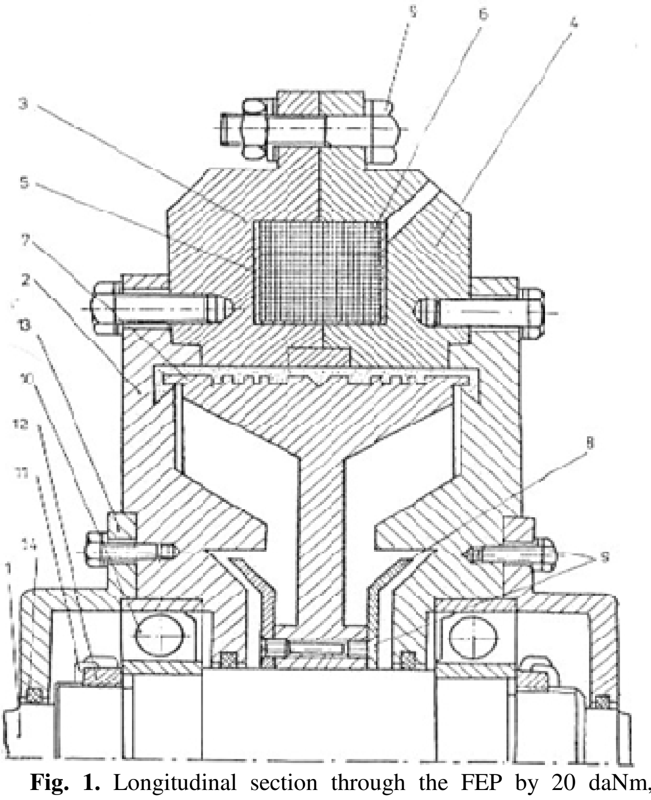

**Fig. 1.** Longitudinal section through the FEP by 20 daNm, 1000 rot./min: 1 - shaft, 2 – shields, 3.4 - stator, 5.6 - excitation coil, 7 – rotor, 8 - traps

After the design calculations and some required construction dimensions, have resulted the following quantities: the total tension (force) magnetomotive of the magnetic circuit$U_{mm}$ = 281 A.sp., for air gap is $U_{m\delta}$ = 160 A.sp.; the excitation current $I_e$ = 0,5 A; w = 562 sp. With EM1 d = 0,47 mm; dimensions $D_{ext}$ x L = 330x140 mm.

In the case when the excitation coil is not powered, the filling material (ferromagnetic powder) must maintain the fluent mobility and sit in special cavities executed for this goal, without affecting the transmission of the rotary motion. The mixture of ferromagnetic powder can be composed of iron carbonyl, iron pulverized or pulverized alloy of steel with nickel or chrome, mixed with magnesium oxide, glass fine dispersed colloidal graphite, etc. [3].

The substances added to the powder are known as separators and are designed to create mixtures that do not crowd and are not wearing out at high temperatures that occur during the operation in long term sliding regime. The agglomeration of filling material has causes significant changes of the magnetic permeability in the working area and of the braking couple transmitted.

## 3.TESTING AND EXPERIMENTAL RESULTS

In comparison with versions of FEP with lower inertia rotor [2], during the execution of our FEP we used magnetic traps of steel with great coercive force and rings of felt for sealing against penetration of ferromagnetic powder in bearings.

Initially, during the dimensioning of the magnetic circuit of the brake, was taken into account its execution from steel casting trademark OT 45, low-carbon, providing a thermal treatment by annealing at 8000C. Taking into account that this is an experimental prototype and for economic reasons, parts of the magnetic circuit (items 2, 3, 4 and 7 of Fig. 1) were made of OL 52.2K rolled steel through mechanical processing, material which presented a guaranteed content of carbon.

The experimental tests were meant to determine the static and the dynamic characteristics, the mechanical characteristic, the optimal volume filling of air gap with ferromagnetic powder, to establish an optimal air gap technologically feasable, and the thermal behavior of the brake.

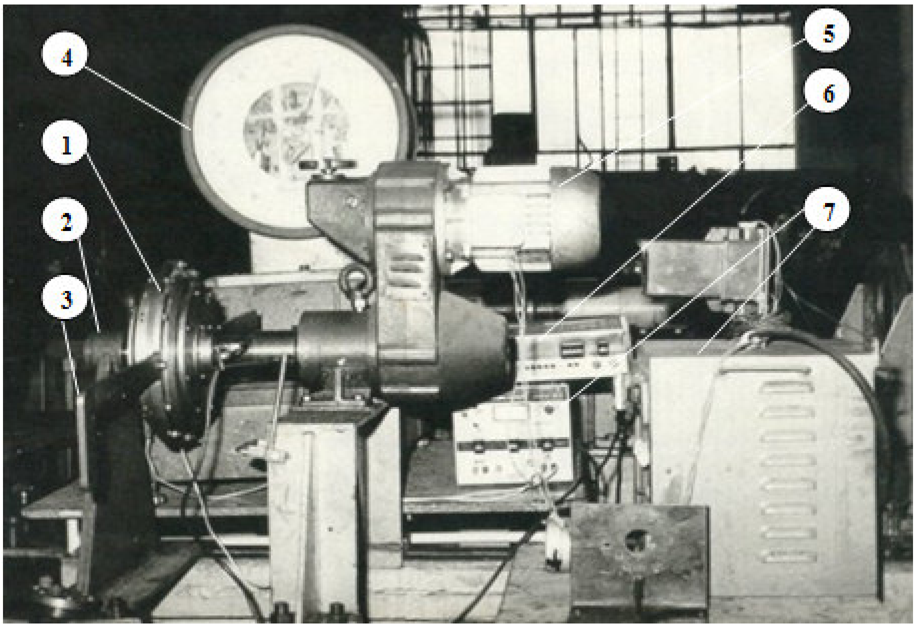


**Fig. 2.** The tested bench: 1 - FEP, 2 - bearing support, 3 - arm measurement, 4 - balance, 5 - motovariator, 6 - turometer, 7 - power sources

**Mechanical characteristic n = f (M)**

Because at the design of the FEP, for a working air gap δ = 1 mm, was noted the existence of a mechanical friction and a high residual torque (> 10% Mn), we decided to to change the air gap with δ = 1.6 mm by processing the rotor. Table 1 presents the experimental data obtained and in Figure 3 is shown the mechanical characteristic by combining the two characteristics results at Ien = 0.5 A.

*Table 1.*

**The values of braking torque**

| **n[rot/min]** | | 0 | 100 | 200 | 300 | 400 | 500 | 600 | 700 | 800 | 900 | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **M [daN.m]** | **δ=1mm** | 0 | 19,3 | 19,4 | 19,4 | 19,4 | 19,4 | 19,4 | 19,4 | 19,4 | 19,1 | 17,8 |
| | **δ=1,6mm** | 0 | 18,4 | 18,5 | 18,6 | 18,6 | 18,6 | 18,6 | 18,6 | 18,6 | 18,6 | 18,1 |

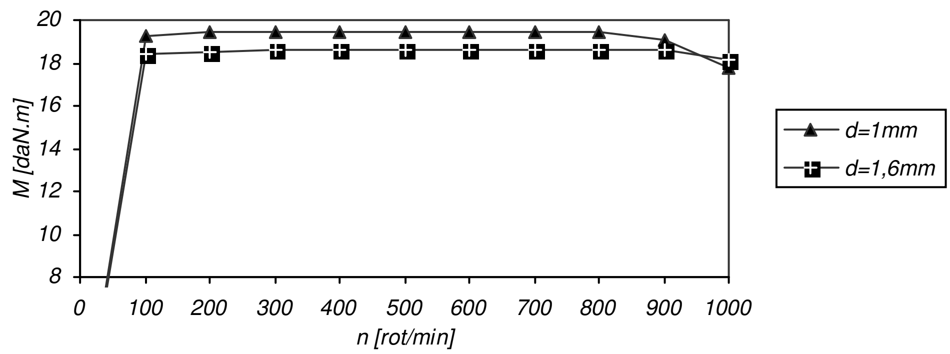


**Fig. 3.** Mechanical characteristics of the FEP for δ = 1 and 1,6 mm

**The static characteristic M = f($I_e$)**

The experimental results are shown in Table 2 and the curves in Figure 4, for different volumes filling up with ferromagnetic powder, through the filling coefficient $k_{uv}$ (ratio of the volume of powder inserted and the real volume calculated of the air gap with a value of about 1 $cm^3$) for the FEP with δ = 1.6 mm

*Table 2.*

**The values of braking torque at different $\delta_{uv}$**

| Ie [A] | | 0 | 0,1 | 0,2 | 0,3 | 0,4 | 0,5 | 0,6 | 0,7 | 0,8 |
|---|---|---|---|---|---|---|---|---|---|---|
| M [daN.m] | **kuv=0** | 0 | 0,1 | 0,2 | 0,35 | 0,5 | 0,7 | 0,9 | 1,15 | 1,2 |
| | **kuv=0,5** | 0 | 0,8 | 1,8 | 4,6 | 7,8 | 10 | 10,6 | 10,7 | 10,8 |
| | **kuv=0,7** | 0,2 | 1,1 | 2,8 | 6,7 | 10,6 | 13,8 | 14,8 | 15,3 | 15,4 |
| | **kuv=0,8** | 0,4 | 1,3 | 4,2 | 8,4 | 12,5 | 16,3 | 17,8 | 17,9 | 18 |
| | **kuv=0,9** | 0,8 | 2 | 5,8 | 10 | 14,7 | 18,6 | 18,8 | 18,9 | 18,9 |
| | **kuv=1** | 2,1 | 3,3 | 7 | 11,4 | 16,2 | 19,2 | 19,3 | 19,4 | 19,4 |

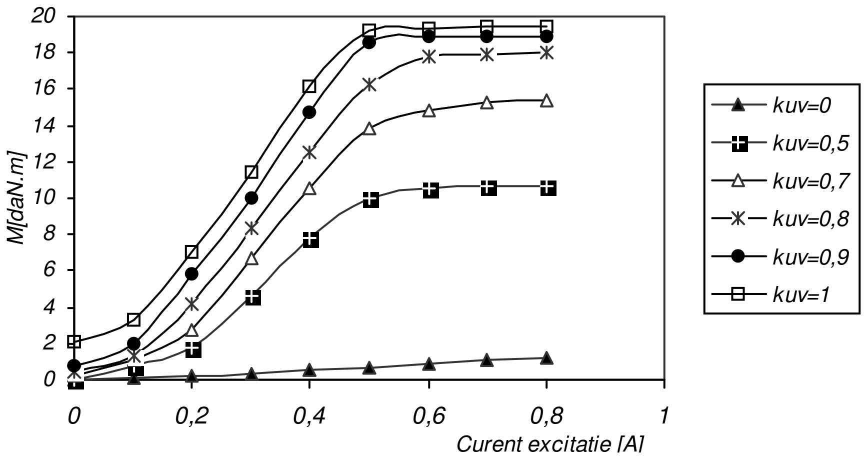


**Fig. 4.** Static characteristic of the FEP for different filling factors $k_{uv}$, at n = 750 rot/min.

## 4. CONCLUSIONS

The nominal braking couple can be reached just in proportion of 93% at a $k_{uv} = 0.9$. When $k_{uv}$ is increased the residual couple increases, and when increase of the excitation current leads to the overheating of the brake requiring additional conditions for cooling.

The optimal value of work air gap should be between 1.4 mm and 2.2 mm for a breakes with a nominal torque of up to 40 daN.m. It should be noted that the quality of the ferromagnetic powder influences the performances of the FEP. In the tests we have used carbonyl iron powder type P8 (Russian) and type L1407 (Austria), the last giving better results.

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