THE HEAVY-DUTY MECHANICAL BRAKES REGIME INFLUENCE ON THE FRICTION COEFFICIENT

A. C. DRUMEANU, N. N. ANTONESCU, I. NAЕ
“Petroleum-Gas” University, 39 Bucharest Blvd., 2000 Ploiesti, ROMANIA; e-mail: drumeanu@mail.upg-ploiesti.ro

SUMMARY
The heavy-duty mechanical brakes operation is characterised by special working conditions concerning the dry friction regime parameters (friction coefficient, temperature on the friction surface, contact pressure and the sliding speed). The braking efficiency of this kind of brakes is mainly influenced by the friction coefficient between two contact surfaces of the braking couple elements. The paper presents some experimental results concerning the influence of the regime parameters (contact pressure, sliding speed and temperature) on the friction coefficient values. This study is based on the investigations concerning the operating behaviour of the mechanical band brakes that equip the drilling draw workses.

Keywords: friction coefficient, heavy-duty mechanical brakes, temperature, contact pressure, sliding speed

1 INTRODUCTION
The dry friction couples of the mechanical brakes are generally composed of two elements. One of them is usually metallic and the other is made from non-metallic composed material ferrodo like. In these conditions, the biggest part of the heat quantity (over 90%) which gives out during braking is taken by the metallic element.

The braking efficiency of the mechanical brakes is influenced by constructive and functional factors. From these, the friction coefficient has the biggest share. The friction coefficient value has to be, in this case, as high as possible. Its value depends on the constructive factors like the type of the couple materials, the roughness of the couple elements surfaces, and also, on the brake regime parameters like the contact pressure and the sliding speed [1]. All these constructive factors and regime parameters influence also the thermal regime on the friction surface, which cause the friction coefficient value variation [2].

The specialty manuals and books present, for different kind of braking couples, the friction coefficient values. It has to be mentioned that these values have an informative character, because of the numerous factors influence. In this case for a rigorous calculus it is recommended to use the friction coefficient values which are experimentally determined in similar work conditions. The starting point for the study of the heavy duty mechanical brakes regime influence on the friction coefficient, was the experimental determinations concerning the operating behaviour of the mechanical band brakes which equip the drilling draw workses. The paper presents the experimental determinations concerning the influence of the regime parameters (contact pressure, sliding speed and temperature on the friction surface) on the friction coefficient values for the heavy-duty band brakes.

2 EXPERIMENTAL CONDITIONS
The experiments were done on a testing stand built for tribo-thermal fatigue studies of the braking couples metallic elements [3]. This testing stand is equipped with a friction couple cylinder-plan like. The test piece has a special form, being tubular inside in order to permit the cooling of the frontal wall trough a cooling tube. The temperature value on the friction surface is indirectly determined, using the temperature value measured on the exterior surface of the test piece (cylindrical part) with a thermocouple, put from the frontal face (the friction surface) at different distances. It was preferred this possibility because the thermocouple assembly by enclosure in an orifice put under the friction surface can create stress concentrators which quickens its cracking process.

The friction couple materials were for the metallic element the middle alloy steels and for the non-metallic element a friction composed material ferrodo like. The main composed friction material characteristics are: the density – 1900 kg/m³; Brinell hardness (150/12.7/30") – 11 HB; friction coefficient at 200°C – minimum 0.40; wear intensity – max 0.977 cm³/10⁶ daN; cross-breaking strength – min 20 MPa; the maximum exploitation temperature value – 400 °C; the maximum contact pressure – 2.5 MPa. Also, the friction couple elements surfaces roughness have values in the range of 1.6 - 3.2 μm.

The experimental regime parameters values were the contact pressure in the range of 0-2.5 MPa; the sliding speed in the range of 0-8 m/s; the temperature on the friction surface in the range of 100 - 1000 °C. These regime parameters values were established according with the real values which were used in the band brakes exploitation.

3 RESULTS AND DISCUSSIONS
For the used dry friction couple, the friction coefficient value depends on the contact pressure, the sliding speed and the temperature.

In Figure 1 is showed the dependence between the friction coefficient and the sliding speed for different contact pressure values. From Figure 1 it can be seen that the increase of the sliding speed and of the contact pressure implies the decrease of the friction coefficient. Also, from Figure 1 it can be observed that for these
parameters, above mentioned, the experimental data are enough scattered.

For the brakes, one of the main parameter that characterise their service is the specific caloric loading \((\rho v)\), that is defined like the product between the nominal contact pressure \(p\) (obtained by the ratio between the normal pressing force and the surface value), and the sliding speed \(v\).

In Figure 2 it is presented the dependence between the friction coefficient and the specific caloric loading determined for different contact pressure values. From this Figure it can be observed that the specific caloric loading increase implies the decrease of the friction coefficient.

From Figure 3 it can be seen that for the temperature values in the range of 500 – 800 °C the friction coefficient value decreases starting from 0.6 to 0.2. Over 800 °C and till 500 °C the variation of the friction coefficient is almost insignificant.

Generally, from Figures 1, 2, 3 it can be observed that the contact pressure increase implies the decrease of the friction coefficient because of its increase implies the increase of the temperature value on the friction surface.

For the temperature values in the range of 600-1000 °C, the regime parameters quantitative influence on the friction coefficient can be emphasised with a multivariate polynomial regression like:

\[
f = 0.794 – 0.214 p – 0.071 v + 1.753 \cdot 10^{-4} t \tag{1}
\]

where: \(f\) is the friction coefficient; \(p\) is the nominal contact pressure, MPa; \(v\) is the sliding speed, m/s; \(t\) is the temperature on the friction surface, °C.

The characteristics of the regression analysis (1) are: the temperature values on the friction surface in the range of 500 - 1000 °C; the variation range for the nominal contact pressure values 0.8-2.5 MPa; the sliding speed range 0.9 - 8.0 m/s; the multiple coefficient of determination value \(R^2 = 0.921\); the partial correlation coefficients values \(r_{fp} = -0.734, r_{fv} = -0.812, r_{ft} = -0.835\); the experimental data dispersion around the regression surface for a 95% confidence interval, in the range of \(±0.06\).

For the temperature values in the range of 100 – 1000 °C the quantitative influence of the regime parameters on the friction coefficient, can be better emphasised with the next multivariate polynomial regression:

\[
f = 0.53 – 0.042 \rho v + 7.037 \cdot 10^{-3} t \tag{2}
\]

where: \(f\) is the friction coefficient; \(\rho v\) is the specific caloric loading, MPa·m/s; \(t\) is the temperature value on the friction surface, °C.

The characteristics of the regression analysis (2) are: the temperature values in the range of 100 – 1000 °C; the nominal contact pressure values in the range of 0 – 2.5 MPa; the sliding speed values in the range of 0 – 8.0 m/s; the multiple coefficient of determination value \(R^2 = 0.834\); the partial correlation coefficients values \(r_{fp} = -0.812, r_{fv} = -0.899, r_{ft} = 0.927\); the experimental data dispersion around the regression surface for a 95% confidence interval, in the range of \(±0.08\).

4 CONCLUSIONS
- between the regime parameters which characterise the heavy-duty mechanical brakes working there exist an strongly interdependence
- the increase of the nominal contact pressure, sliding speed and temperature of the friction surface generally implies the decrease of the friction coefficient value;
- the temperature on the friction surface has the major share on the friction coefficient variation, this fact can be demonstrated by the high values of the partial correlation coefficients between the friction coefficient and the temperature (see the regression analyses above presented);
- for the dry friction couple materials, which were used in this study, the best working temperature is in the range of 100-600 °C;
- the results of this study can be used both in the exploitation and in the design of the heavy-duty mechanical brakes.

5 REFERENCES
Figure 1: The dependence between the friction coefficient and the sliding speed for different nominal contact pressure values

Figure 2: The dependence between the friction coefficient and the specific caloric loading for different nominal contact pressure values

Figure 3: The dependence between the friction coefficient and the temperature on the friction surface