Comparative analysis of tribological properties of friction bands used in lifting and transport machinery

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Abstract. The comparative tests of asbestos-containing EM-1 and asbestos-free BAC friction bands were conducted. The results indicate that BAC friction bands provide more stable friction coefficients. The usage of BAC friction bands may reduce maintenance costs for the brakes of powered industrial machines.

1. Introduction

Drum and band brakes are widely used in traveling cranes as they can develop high braking torque and withstand high loads [1]. The stability and efficiency of drum brakes is evaluated by the breaking torque, friction bands temperature and their wear.

Considerable part of friction bands in use is manufactured using the asbestos fiber. The World Health Organization acknowledges asbestos as carcinogenic agent, for instance, the usage of asbestos in the most of developed countries is limited or forbidden [2]. The developing countries are sharing the same path of gradual enhancing of restrictions on use of asbestos in industry and construction.

Considering the possible restrictions on use of asbestos in Russian Federation the need of replacing asbestos-containing bands with asbestos-free ones may arise. Thus, it is reasonable to conduct comparative tests of such materials.

2. Experimental part

A widely used Russian asbestos-containing elastic material EM-1 (GOST 15960-96) and Polish composite friction band BAC were chosen as comparison objects. The BAC band is woven band of ceramic yarns with very thin monofilaments reinforced with brass wire and soaked with composition of synthetic and natural resins. The specifications of these bands are shown in table 1.

Table 1. Band specifications.

|                      | EM-1 | BAC |
|----------------------|------|-----|
| Max. unit pressure, MPa | 1.5  | 1.2 |
| Max. rotational velocity, m·s⁻¹ | 18   | 20  |
| Max. temperature of constant operation, °C | 200  | 350 |
| Nom. friction coefficient | 0.44 | 0.40 |
The comparative experimental evaluation of friction and wear behavior of these materials was conducted. The disc-shoe experiment was performed on the modernized II 5018 machine [3] under parameters matched to real-life ones. The photo of II 5018 machine is shown in figure 1.

![Figure 1. Modernized II 5018 machine.](image)

The aim of this experiment was to assess the friction coefficient and the wear intensity under different loads.

9 specimens of each material were manufactured. The Ø 50 mm disc counterfaces were lathed from St45 GOST 7417-75. Each specimen was paired to its own disc to get rid of the counterface wear influence. The EM-1 specimens were milled shoe-shaped. The BAC specimens were glued to 1 mm thin St45 shoes using the VK9 compound. The normal load was set to 200, 300 and 400 N. The disc rotational frequency was set to 200, 300, 400 rpm. The duration of each test was 450 sec disregarding the break-in period. The measurement and registration of braking torque and contact temperature was conducted during the tests. The temperature was measured by K-type thermocouples mounted at 45° angles to the contact surface. Additional calculations of friction forces and friction coefficients were made. The weight wear was evaluated using the VLR-200 analytical scales. The linear wear was not evaluated due to inappropriate materials structure. The counterface wear was insufficient and was not taken into account.

The rotational frequencies chosen correspond to low rotational velocities of the friction track (1.046 – 2.095 m·s⁻¹). Taking nominal contact area into account, 200 N load approximately corresponds to 1.04 MPa unit pressure, 250 N load – to 1.3 MPa, 300 N load – to 1.57 MPa. It was noted that actual contact area for BAC material is bigger than nominal, so the actual unit pressure was somewhat lower. Thus, at 300 N load the unit pressure was exceeded by 5% and 31% for EM-1 and BAC materials correspondingly. During testing the specimen temperature did not exceed the specifications.

3. Results
The experimental data was analyzed; the graphs of friction coefficients and specimen temperatures were plotted (figures 2-5). The experimental data is shown in table 2.
### Table 2. Experimental data.

|   | P, N | V, rpm | M, N·m | T<sub>final</sub>, °C | F<sub>friction</sub>, N | F<sub>friction average</sub> | J, mg·min<sup>-1</sup> |
|---|------|--------|--------|----------------------|----------------------|-----------------------------|---------------------|
| 1 | 200  | 200    | EM-1   | 2.33                 | 93.02                | 0.46                        | 0.500               |
| 2 | 200  | 300    | EM-1   | 3.99                 | 159.57               | 0.75                        | 1.025               |
| 3 | 200  | 400    | EM-1   | 3.90                 | 155.98               | 0.80                        | 1.694               |
| 4 | 250  | 200    | EM-1   | 3.26                 | 130.41               | 0.52                        | 1.106               |
| 5 | 250  | 300    | EM-1   | 3.35                 | 133.90               | 0.54                        | 2.638               |
| 6 | 250  | 400    | EM-1   | 3.69                 | 147.72               | 0.60                        | 2.125               |
| 7 | 300  | 200    | EM-1   | 2.22                 | 88.95                | 0.30                        | 0.225               |
| 8 | 300  | 300    | EM-1   | 1.82                 | 72.62                | 0.25                        | 3.213               |
| 9 | 300  | 400    | EM-1   | 2.48                 | 99.25                | 0.33                        | 1.581               |

*The destruction of specimen after t=5 min.

**Figure 2.** Friction coefficients of EM-1 material.
Figure 3. Temperatures of EM-1 material.

Figure 4. Friction coefficients of BAC material.
4. Discussion

The experimental data analysis showed different specimen behavior under nominal loads. In average the EM-1 material heats up to higher temperatures yet provides higher friction coefficients. In mode №1 the final temperature and average friction coefficients are pretty much the same. The exaggeration of test conditions gives ambiguous results. So, increasing the rotational velocity at 200 N load results in really high friction coefficient of 0.8 at temperature of 150°C. This friction coefficient is twice higher in comparison to BAC band. The final temperature is 2.5 times higher in comparison to BAC band. In modes 5-6 (which are harder than modes 2-3) drastically lower friction coefficients were observed while the temperatures were higher. After exceeding the nominal unit pressures in modes 7-9 the friction coefficient turned out to be remarkably low, 0.25-0.33 while the temperature varied from 73°C to 103°C. There values are significantly lower than nominal values, and the temperatures are lower in comparison to previous modes.

The BAC band performance is much more stable. So, the friction coefficients under nominal loads were 0.4±10%. It must be noted that in modes 2-3 the EM-1 band provided the highest friction coefficients while the BAC band – the lowest. In most modes the temperature of BAC band was 1.5-2 times lower in comparison to EM-1 band. In modes 7-8 the performance similar to EM-1 band was noted: the average friction coefficients were lower than nominal, the specimen temperatures were quite low. During the test in mode 9 (300 N, 400 rpm) the friction coefficient was approximately 0.38 at temperature rise up to 90°C. At the end of the fifth minute of experiment the destruction (interlaminar shear) of the specimen took place.
The average weight wear following 8 tests was 1.56 mg·min\(^{-1}\) for EM-1 and 0.88 mg·min\(^{-1}\) for BAC bands. Tests №9 were not included due to destruction of BAC №9 specimen with significant loss of material. Visual estimate also showed much higher wear levels of EM-1 material. Also, the edge chipping of EM-1 material was noted. The images of specimen sliding surfaces are shown in figures 6-7.

5. Conclusions
The comparative tests have shown that while operating the brake systems in nominal modes asbestos-containing EM-1 material provides higher braking torque at the price of lower wear resistance, higher operating temperatures and higher ecological damage. The scattered values of friction coefficients in different operating modes were noted. The BAC bands performance is much more predictable while providing stable nominal friction coefficients with scatter of ±10% and lower operating temperatures, as well as lower weight wear values. The performance of both materials under excess load is unsatisfactory with friction coefficients being lower than nominal. The BAC bands provide stable braking parameters at the same time proving 1.7 times higher wear resistance, thus usage of these bands is seen more economically viable: the band replacement frequency is lower, as well as the maintenance of brake systems. Lower average operating temperatures may result in increasing the life cycle of lubricants in the units of brake systems.

References
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