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INFLUENCE OF THE CONTACT PRESSURE ON THE WEAR BEHAVIOUR OF ASBESTOS – FREE FRICTION MATERIAL THROUGH PIN-ON-DISK TRIBOMETER

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Abstract. In this paper a tribological experimental analysis on a commercial asbestos – free friction material has been carried out. The aim of the investigation is to evaluate the influence of the contact pressure on the wear performances of the friction material, by the use of a pin–on–disk tribometer. Wear volume and wear rate parameters have been evaluated considering the contact load as main influence factor. A thin layer of sample material has been added to the rotating disk of the tribometer and matched to a counterface pin, in order to establish the coefficient of friction and the wear rate, under several sliding condition and different running in time test. As post processing evaluation, the surface analysis of the sample material has been carried out; the profiles of the sliding path have been used to measure the wear volume and formulate a wear rate parameter. It has been observed that the pressure contact is the main parameter to affect the tribological performances, such as temperature interface, friction and wear: higher contact pressure has led to higher values of these parameters. The most relevant result has been achieved by the evaluation of the wear rate in time; the experimental campaign has been carried through 1 h wear test. Under different test operating conditions, different trends of the wear rate in time have been observed.

Keywords. Dry friction, wear, surface analysis, pin-on-disk test, contact pressure.

1. INTRODUCTION

The friction brake materials play an indispensable role in safety operation of vehicles and industrial equipment. Friction and wear behaviours of friction materials (FM) are considered subjects of great research interest. The friction braking conditions, such as temperature, pressure, and velocity, affect the friction and wear performance of friction materials; generally, the friction coefficient tends to be low while the wear rate increases rapidly under condition of high temperature, braking pressure, or initial braking speed [1]. In the last few years, the development of brake friction materials has led to the improvement of the wear resistance and stable friction during brake applications, under a wide range of operating conditions, such as vehicle speed and braking force [2–5]. Recent research has been pointing out on the composition of friction materials FM, composites containing several ingredients incorporated to the friction material matrix. Among the components used in brake friction materials, reinforcing fibers have played an important role in wear resistance and friction stability [6–9]; moreover, an increasing attention has been given to eco-friendliness of special friction material formulations, free from polluting ingredients (e.g. asbestos or copper) [10–12].

One of the most relevant aspect of investigation of friction material is linked to the tribological properties, such as the friction and wear phenomena affecting the FM in contact with a mating surface. Many studies have proved performance of the friction material, through experimental testing of the coupled FM in dry – contact condition [13–15]. The aim of this paper is to evaluate the tribological behaviour of a commercial friction material, characterising its wear parameters in different sliding condition, with a pin–on–disk contact coupling configuration.

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For instance, in [16] the tribological behaviour of a commercial brake pad material has been investigated. The tribopair tests have been performed under dry sliding conditions by the use of a pin-on-disk apparatus; the pin sample material has been coupled to a cast iron counterface disk. It has been observed that the wear is strongly affected by temperature, showing a transition from mild to severe temperature at about 170 °C. On one hand, pin–on–disk experimental analysis has been focused on temperature influence on friction performance of brake material [17, 18]; on the other hand, the operating sliding condition have been investigated and tribological tests have been carried out.

In [19], the preliminary experimental campaign has shown the frictional behaviour of common materials for brake and clutch facings under the influence of the sliding parameters. As in the previous cases, also in this research the coupled materials have been tested using a pin–on–disk contact geometry. A series of 1 hour experiments to simulate the operating conditions at different levels of loading and sliding speed have been planned. Recently, experimental investigation has been having much interest in eco – friendly friction materials [20, 21]. In [11] a new generation of brake friction material Cu – free has been tested; the experimental pin–on–disk apparatus has been used to evaluate the friction, wear and airborne particle emission from two Cu-free commercial brake pads used in the Europe.

The aim of the investigation is to evaluate the influence of the contact pressure on the wear performances of the asbestos – free friction material, FTL225 by the use of a pin–on–disk setup. Wear volume and wear rate parameters have been evaluated.

2. EXPERIMENTAL SECTION

2.1. Materials.

Since the tribological tests have been carried out by the use of a pin–on–disk geometry apparatus, a thin layer of sample material has been coated on the tribometer rotating disk (figure 1). The sample is a commercial asbestos – free friction material, FTL225 produced by Friction Technology Ltd. The thickness of the sample layer is 1.3 mm and the roughness analysis has displayed values of R_a=0.9 µm and R_a=1.1 µm in the parallel and perpendicular direction to the fiber respectively. The roughness profile, the waviness and the total profile, corresponding to the purple, red and blue lines respectively, are shown in figure 2.

Figure 1. Sample material added to the rotating disk of the test apparatus.

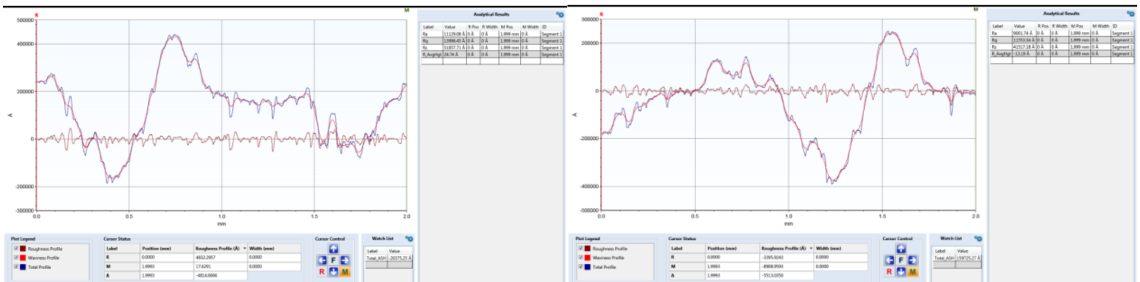

Figure 2. Sample roughness profiles.

2.2. Test rig and test condition description.

Tests have been carried out under different operating conditions to investigate the tribological performance of FTL material, pin–on–disk, by the use of NANOVEA T500 tribometer at the research centre ENEA in Brindisi. Firstly, test conditions have been set up considering an hertzian contact pressure of $p_m = 1.0\ MPa$ and a sliding velocity of $v = 6.1\ m/s$, in accordance with the SAE J661 standard. Therefore, the operating settings have been chosen so to compare the experimental results to the datasheet tribological information: in this case values for the contact pressure and the sliding velocity, respectively $p_m = 0.3\ MPa$ and $v = 8.0\ m/s$. The experimental tests aim to point out not exclusively the performance related to friction of the tribological coupling, but also the wear phenomena influencing material surfaces. The table 1 summarizes the performed test conditions.

Table 1. Experimental test conditions.

Test number	Contact pressure, MPa	Sliding velocity, m/s	Radius, mm	Revolution per minute, min^{-1}	Time duration, h
1_3	1.0	6.1	35	1665	0.5
2_1	1.0	6.1	30	1942	1
2_2	1.0	6.1	22	2649	1
2_3	1.0	6.1	14	4163	1
3_1	0.3	8.0	35	2184	1
3_2	0.3	8.0	25	3057	1
3_3	0.3	8.0	17	4495	1

Contact interface temperature has been measured in real-time and a system for the air suction has been set near the tribological conjunction, in order to keep a homogeneous pin temperature field. The most relevant outputs from the experimental analysis are the average and maximum values of the CoF, coefficient of friction, and the wear rate, calculated as the ratio between the wear volume and the energy dissipation in the sliding contact. Moreover, the post processing analysis allowed to evaluate the roughness profiles of the sample material at the end of each test and the images of the sliding paths on the disks. The roughness profiles have been acquired in the parallel and transversal direction with respect to the fiber.

3. RESULTS AND DISCUSSION

3.1. Frictional test.

In this first experimental campaign, 1h length experimental tests have been performed. In operating conditions of $p_m = 1.0\ MPa$ and $v = 6.1\ m/s$ (SAE J661), three tribotests have been performed at different disk radius, in order to define a more accurate data analysis of the results. The table 2 shows the experimental results.

Table 2. Test results – SAE J661 standard condition 1 h.

Test number	Temperature, °C	CoF_avg	CoF_max	Sliding distance, m	Volume, mm^3	Wear rate, mm^3/kWh
1_3	83.56	0.342	0.397	10979.01	10.55	181.93
2_1	76.10	0.355	0.435	21952.36	17.82	146.02
2_2	67.78	0.235	0.394	21959.15	14.35	117.51
2_3	85.80	0.379	0.481	21960.66	17.77	145.52

The test number 1_3 has been performed firstly considering a run time of 0.5 hours; since it has shown unremarkable wear path, it has been set up that the following tests should have lasted 1 hour. Focusing on the wear performances, it has been observed that for volume and wear rate the measured values are almost the same in parallel and transversal direction; therefore, only one measurement has been reported. The average value of wear rate and its standard deviation have been evaluated.

Table 1. Average value of wear rate – SAE J661 standard condition 1h.

Contact pressure, MPa	Sliding velocity, m/s	Wear rate, mm³/kWh	Standard deviation, mm³/kWh
1.0	6.1	148	26

The figure 3 and 4 shows the 3D surface acquisitions related to test number 1_3, 2_1 and 2_3.

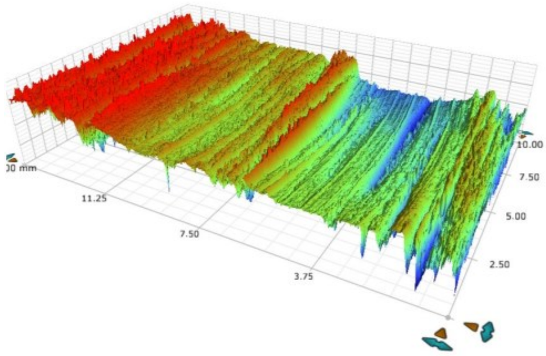

Figure 1. 3D surface acquisitions related to test number 1_3 and 2_1.

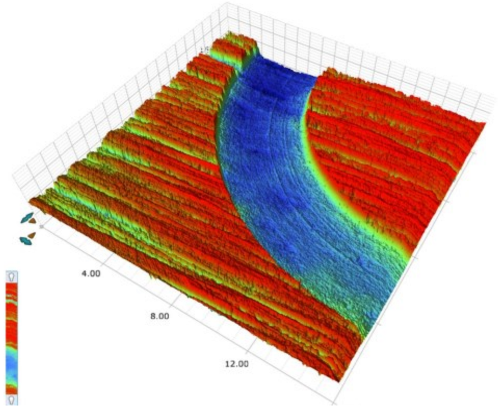

Figure 2. 3D surface acquisitions related to test number 2_3.

Especially for the test 2_3, the acquisition image has revealed the track of the sliding pin on the disk. Clearly, the pin has caused wear in the counterface mating material, providing the arise of a sliding path on the friction layer added on the disk. Further, this phenomenon has been proved also by the roughness profiles, as showed in figure 5.

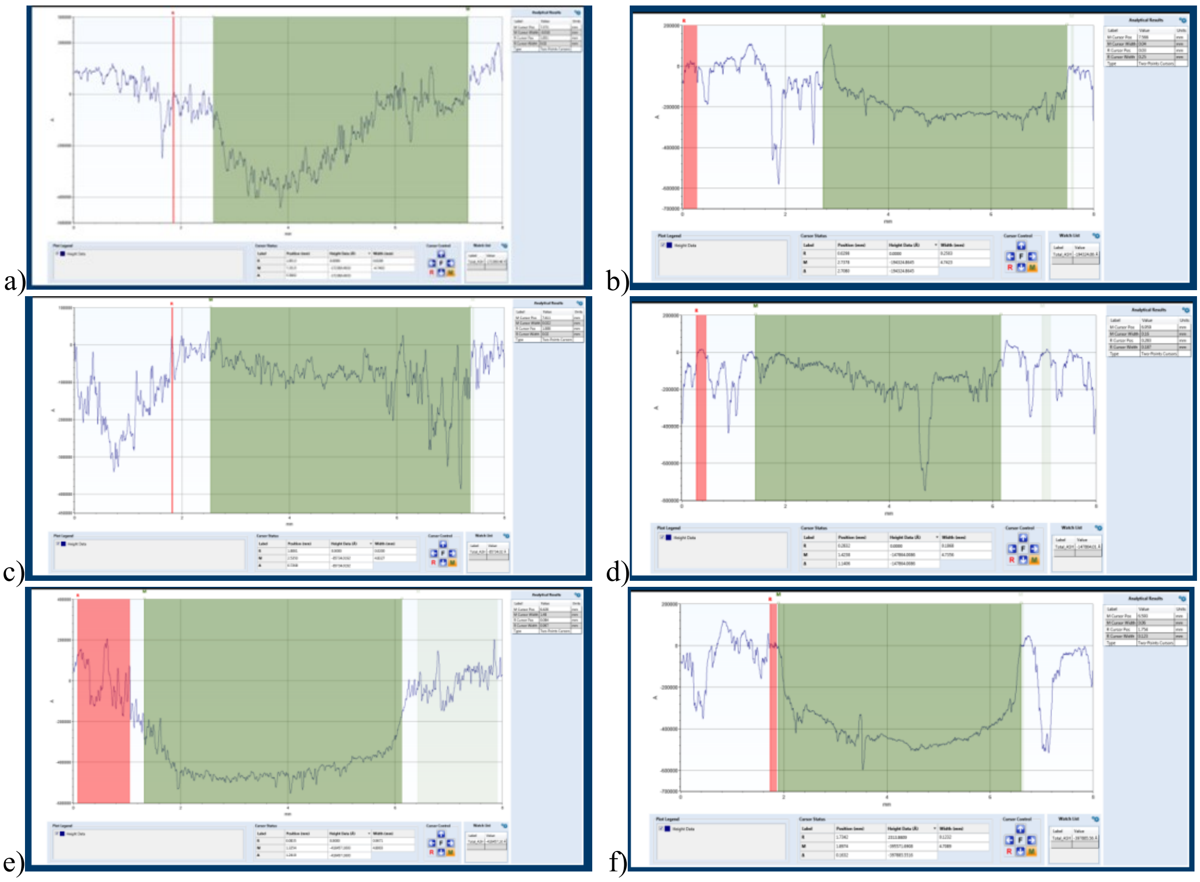

Figure 3. Roughness profiles: a) Test 1_3 parallel fiber profile; b) Test 1_3 transversal fiber profile; c) Test 2_2 parallel fiber profile; d) Test 2_2 transversal fiber profile; e) Test 2_3 parallel fiber profile; f) Test 2_3 transversal fiber profile.

The profile investigation for test 2_3 has detected a bathtube curve shape, both in parallel (//) and transversal (T) directions; otherwise for the tests number 1_3 and 2_2 the profiles have appeared much flatter. This analysis has confirmed the trend of the wear performance parameters (volume and wear rate): the data in table have shown higher values for the test 2_3, compared to the 1_3 and 2_2.

The second part of experiments with 1h length has considered the operating conditions of p_m=0.3 MPa and v=8.0 m/s (FTL225 datasheet); also in this case three tests have been carried out at different disk radius, even achieving the same sliding distance. The wear volume and the wear rate have been evaluated both in parallel and transversal directions.

The results are showed in table 4.

Table 2. Test results – FTL225 datasheet test condition 1 h.

Test number	Temperature, °C	CoF_avg	CoF_max	Sliding distance, m	Volume, mm^3	Wear rate, mm^3/kWh
3_1	20.47	0.024	0.077	28802.59	// 5.37	// 118.68
					T 2.77	T 61.24
3_2	23.24	0.031	0.083	28796.94	// 5.40	// 119.42
					T 4.33	T 95.81
3_3	21.60	0.195	0.264	28793.17	// 5.13	// 113.31
					T 2.39	T 52.88

The data in table have shown values of wear parameters very close for each test. Unlike the previous test condition, in this case, the wear performances have shown great difference between the parallel and transversal direction; generally, the wear volume and wear rate have been observed to be higher in parallel fiber direction. The mean value of the wear rate and the standard deviation have been calculated:

Table 3. Average value of wear rate – FTL225 datasheet test condition 1 h.

Contact pressure, MPa	Sliding velocity, m/s	Wear rate, mm^3/kWh	Standard deviation, mm^3/kWh
0.3	8.0	94	30

As example, the figure 6 shows the path of the pin sliding on the friction material for one of the tests at p_m=0.3 MPa and v=8.0 m/s.

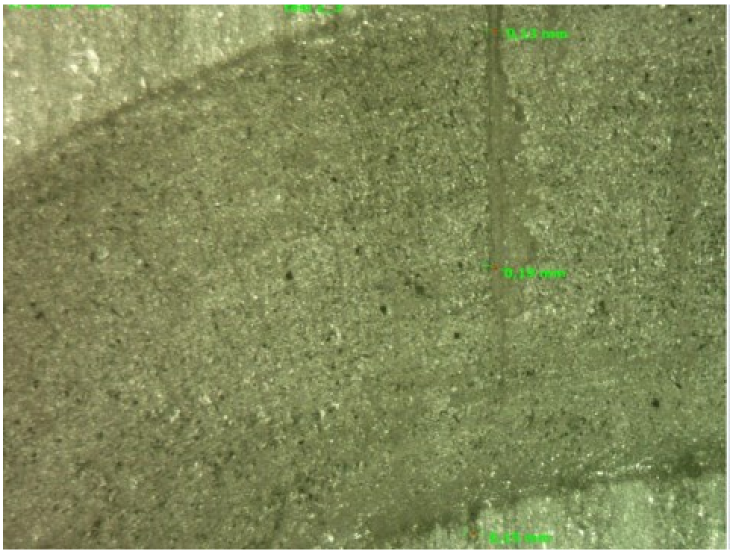

Figure 4. Pin sliding path on the friction material related to test number 3_3.

The roughness graphs have proved the data from table, showing profiles mostly similar for the three tests. Moreover, there is no evidence of remarkable wear, as it has been observed for the previous operating conditions, which sample surface acquisitions have shown bathtube shaped profiles (figure 7).

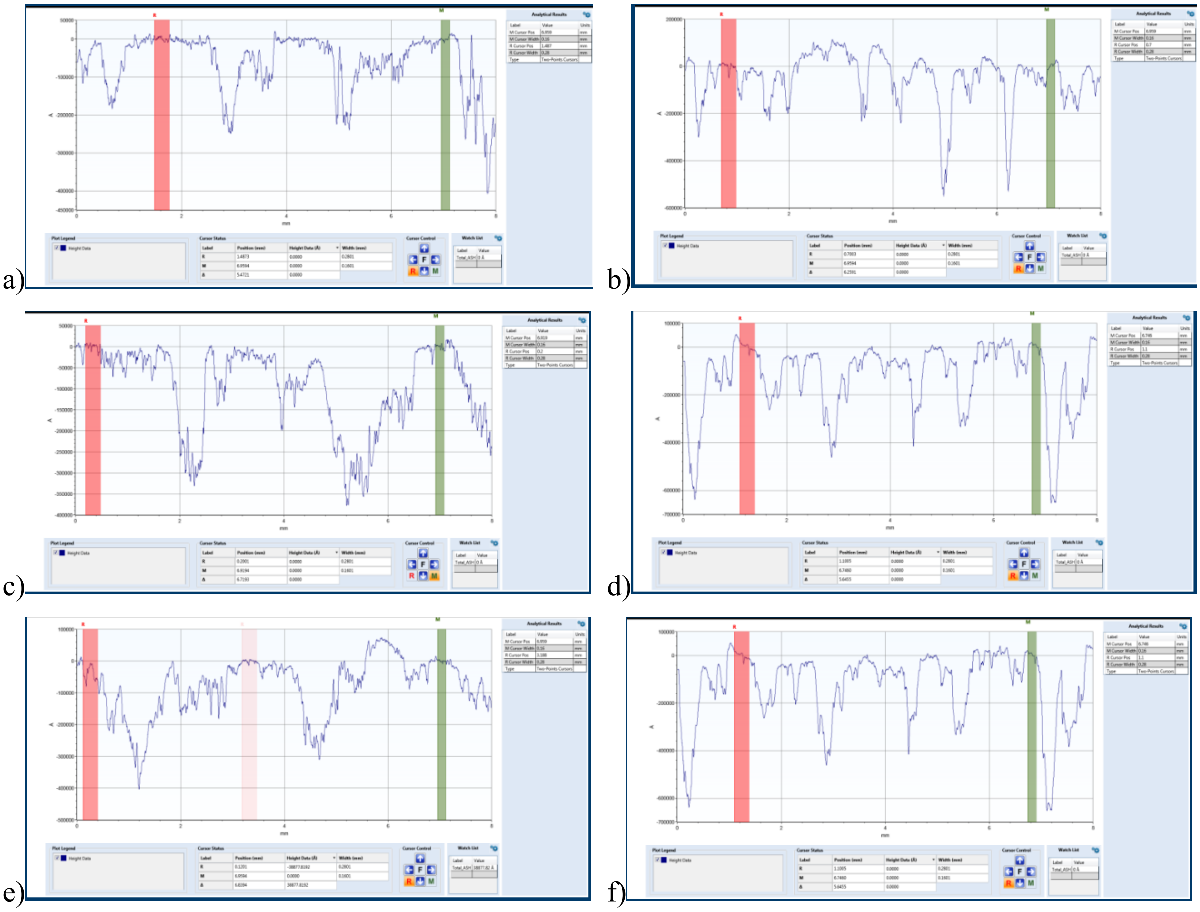

Figure 7. Roughness profiles: a) Test 3_1 parallel fiber profile; b) Test 3_1 transversal fiber profile; c) Test 3_2 parallel fiber profile; d) Test 3_2 transversal fiber profile; e) Test 3_3 parallel fiber profile; f) Test 3_3 transversal fiber profile.

4. CONCLUSIONS

The tribological analysis of sample material FTL225 has been carried out by experimental tests, through a pin–on–disk experimental setup. The performance investigation concerning friction and wear under several operating conditions has led to the following main findings:

- Operating test conditions related to SAE J661 standard have provided higher values of interface temperature, coefficient of friction and wear parameters, compared to the tests with the operation settings from the FTL225 datasheet. Mostly the contact pressure has affected the tribological performance, since the SAE J661 standard imposes higher value of $p_m = 1.0\ MPa$ compared to tests at $p_m = 0.3\ MPa$ according to the datasheet, even if the sliding velocity has been set up lower.
- The tests at higher contact pressures have shown more remarkable wear, observed both from wear volume and wear rate data. Moreover, it could be observed a bathtube shape of the sliding path profiles acquired on the sample material. The depth of the profiles increased with the time duration of the experimental test.
- At lower contact pressure, the profile measurements are mostly flat for short time duration tests.

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