

Genesis of the Third-Body at the Pad-Disc Interface: Case Study Of Sintered Metal Matrix Composite Lining Material

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ABSTRACT

During braking, third-body flows and layers govern friction mechanisms, which are fully responsible of the friction coefficient and wear. In the context of development of brake friction pairs, the involved tribological circuit has to be well understood and mastered. This paper concerns a sintered metal matrix composite used for TGV very high speed train. A series of low-energy stop brakings allows a detailed study of the third-body formation at the pad-disc contact. The pin surface is observed after each test. The evolution of the rubbing-area expansion all along the series is explained, and the friction behaviour, typical of the studied friction material, is related to the formation of a well-established third body at the pad-disc interface.

1. INTRODUCTION

During braking, dissipation of high energy due to friction leads to high thermal and mechanical solicitations of the friction pair of materials, involving detachment of debris and particles. Interfacial layers form in the contact, composed of a mixture of metallic oxides and ingredients of pad materials, most of the studies referring to organic composite lining materials [1-5]. These layers bear the load and contribute to physical mechanisms induced by friction at the interface [6-8]. Their role on friction and wear, and the consequences in terms of energy dissipation, friction induced vibrations or squealing need to be well understood in the context of a drive for eco-friendliness of friction materials along with the raised

expectations for superior performance.

The present study of friction mechanisms is based on the third-body approach proposed by Godet [9,10]. During braking, a tribological circuit is activated, involving a third-body composed of flat plates bearing the load and powder layers fed by flows of particles carried by the disc rotation (Figure 1) [11-13].

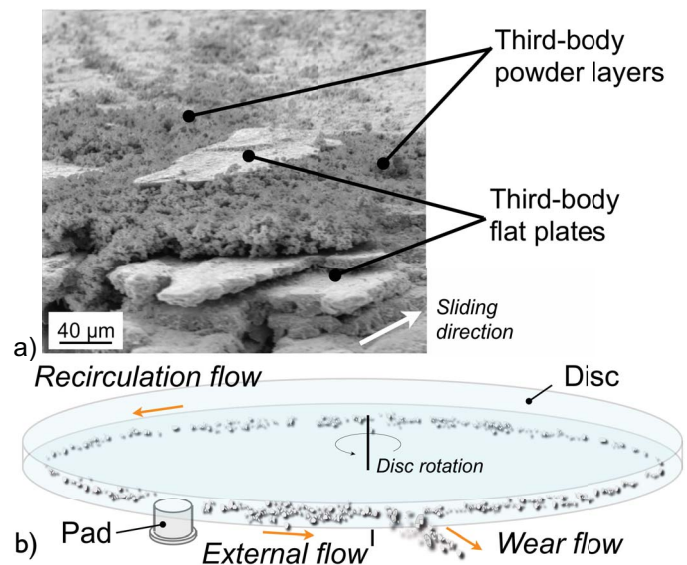


Fig. 1. Tribological circuit activated in braking: a) third-body flat plates and powder layers on the rubbing-surface of a sintered metal matrix pad, b) Flows of third-body particles involved by the disc rotation

This paper focuses on the early stages of third-body formation at the friction interface in the case of a sintered metal matrix composite lining material rubbing on a low-allowed forged steel disc. The section 2 presents the disc-brake pair of materials and specimens used in this study. Experimental conditions are given in section 3, while the tribological behaviour is presented in section 4. The three following sections consist in a detailed analysis of the progressive expansion of the rubbing area at the pad-disc interface, which finally allows a reconstitution of the third-body genesis in the contact and correlations with the tribological behaviour.

2. MATERIALS AND SPECIMENS

The studied materials are used on disc brakes of the TGV very high-speed train. The disc material is 28CrMoV5-08 steel forged and heat treated, leading to a tempered martensitic microstructure with high mechanical properties up to high temperatures and a good fatigue behaviour under thermomechanical loading. For experiment, the disc geometry has an outer diameter of 355 mm, an inner diameter of 180 mm and a thickness of 20 mm.

The pad material is a sintered metal matrix composite reinforced by particles (MMCp), elaborated according to a solid phase process from bronze and iron base, containing mainly graphite and ceramic particles. Its chemical composition is given in Table 1. Resulting from empirical experience, this material presents good thermomechanical properties even at high temperature, good wear resistance and stability of friction coefficient, and no excessive aggressiveness of the disc-rubbing surface.

Table 1. Chemical composition of the MMCp sintered pad material (wt %).

Cu	Fe	C	Si	Al	O	Sn
55	20	7.7	3.3	2.25	5.6	2.7

The pin was directly withheld from commercial lining used on TGV very high-speed train (Figure 2a). For the test, the original pin diameter was reduced to 20 mm. This choice corresponds to a good compromise concerning the pin friction-surface area. On the one hand, the contact area is large enough regarding the heterogenous-MMCp pad-material, typical dimensions of physical phenomena induced by friction and the representativeness of plan-to-plan contact. On the other

hand, it is small enough to allow rather uniform field distributions (sliding velocity, pressure, temperature, etc.). At last, this small pin friction-surface area makes the observations of the friction surfaces easier.

The pin friction surface was polished up to 1 μm granularity sandpaper, and then carefully cleaned in alcohol by ultrasonic waves and dried. Figure 2b presents an optical micrograph of the polished surface of a sintered pin, showing the CuSn-Fe matrix, graphite and ceramic particles (SiO_2 , Al_2O_3). The average size of sintered particles is in the order of one micrometer.

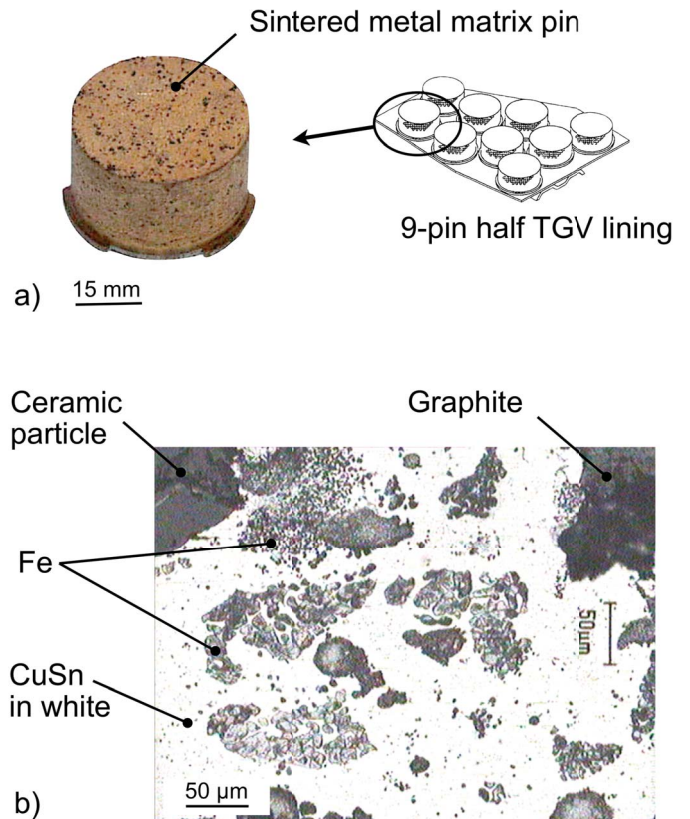


Figure 2. Sintered metal matrix composite material. a) TGV very high speed train lining, b) microstructure of the sintered metal matrix composite material.

3. EXPERIMENTS

Tests were performed on an inertial tribometer, which was specifically designed to reproduce at a scale adapted to laboratory studies braking conditions observed at full-scale for railway braking applications [14,15].

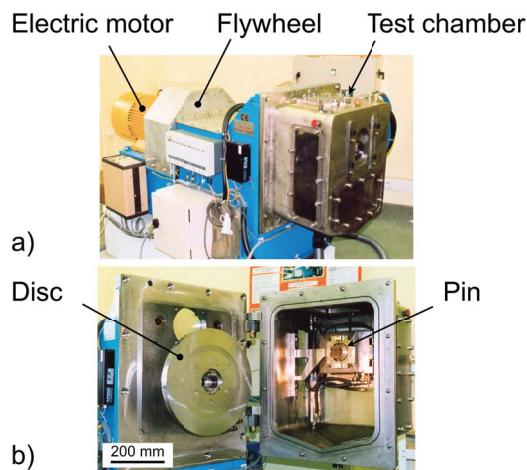


Figure 3. a) Experimental device for stop-braking tests, b) pin and disc mounted in the test chamber.

In order to investigate the third body formation, development and flows in the contact between the two virgin first-bodies, a series of five successive low-energy stop-braking tests was performed. Table 2 gives experimental parameters adopted in the test series, the normal load value increasing from one test to the next. Indeed, the pin presented after polishing a slightly curvature of its polished surface, then the apparent contact area progressed from one test to the next. Hence, the normal load was adjusted at the beginning of each test in order to obtain approximately the same mean contact pressure over all the five tests.

Table 2. Series of five low-energy stop-braking tests: experimental conditions.

Test number	1	2	3	4	5
Normal load [N]	30	40	70	95	105
Initial sliding velocity [m/s]	24				
Dissipated energy [kJ]	27				
Mean apparent area [mm ²]	70	120	170	205	250
Mean contact pressure [MPa]	0.43	0.33	0.41	0.48	0.47

Note that the choice of the normal load value was not so easy because the apparent contact area development was in fact unknown at the beginning of tests. Moreover, the mean contact pressure decreases as the test goes along while the apparent contact area expands. Contact pressure and apparent area values given in Table 2 correspond to mean values determined after each test from rubbing-area evaluation of the pin surface as

explained in section 5. Whereas these considerations, the pressure range obtained over all the five tests is limited and the mean contact pressure values are in accordance with the in-service TGV conditions [11].

To study the progression of the third-body formation through the test series, a map of the whole pin surface was made and the specimen was methodically observed after each test. Fig. 4 shows the location of the twelve areas systematically observed at different magnitudes after each test of the series. In this figure (and the following), the white arrow indicates the disc vs pin sliding direction during the tests. It has to be noted that, regarding this sliding direction, areas 1 and 2 are in the front-region of the pin surface while areas 11 and 12 are in the rear-region of the pin surface. Regarding the rotation of the disc, areas 6 and 10 on the left of the figure are towards the inner radius in the pin inner-region while areas 3 and 7 on the right are towards the outer radius in the pin outer-region. The last four remaining areas are located in the central region of the pin surface.

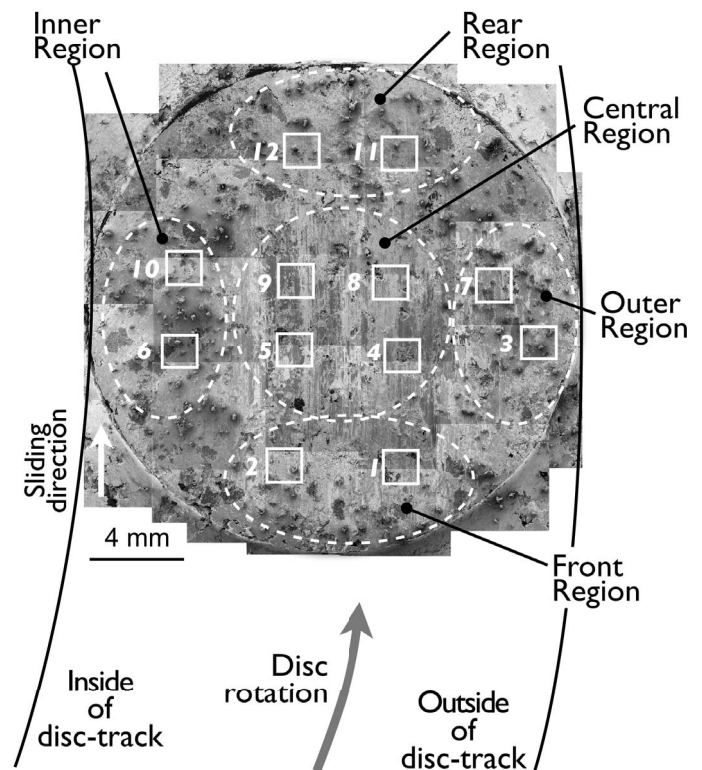


Fig 4 Map of the pin surface: regions of interest of the friction surface and location in white of the twelve areas systematically observed along the test series.