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Observations of dry particles behaviour at the tyre/road interface

Simon Changarnier[a,*], Yosra Hichri[b], Véronique Cerezo[b], Minh-Tan Do[b], Ferdinando Salvatore[a], Hassan Zahouani[a]

[a] *Université de Lyon, ENISE, LTDS, UMRS CNRS 5513, 58 Rue Jean Parot, 42023, Saint-Etienne, France*
[b] *IFSTTAR, AME-EASE, 44344, Bouguenais, France*

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ABSTRACT

Previous studies highlighted that friction value measured on real road surface textures covered by particles depends on particle sizes. This paper focuses on identification of particles behaviours at the tyre/road interface in the presence of particles. Identification is made by visual observations through high-speed camera, focus-variation microscopy and Scanning Electron Microscopy on the contaminated surface as scratch analysis on the surface. Two particle types were collected into samples picked next to roads. They are composed of clay and quartz which have different behaviours at the interface and affect the friction. Clay has a lasting effect due to its adhesive behaviour. Quartz has a scratching and rolling behaviour and is quickly ejected to the contact area due to a pinching effect.

1. Introduction

During a dry weather period, there is a deposit of particles (dust, debris from tyres and the road, etc.) on the road. It is widely accepted that longer is this period, more particles are gathered. All around the world further studies [1–7] have shown that most particles are mainly smaller than 125 μm and concentrations of particles vary from 10 to 55 g/m^2.

When rainfall is starting, after a long dry period, statistics show that traffic crashes increase [8]. This is due to the accumulation of particles reducing the friction coefficient between the tyre and the road surface [9–11]. This phenomenon is called the summer ice phenomenon.

Nevertheless, Mills et al. [12] and more recently Y. Hichri et al. [13,14] have observed that friction is already reduced on dry contaminated roads. These authors measured the friction by means of a Skid Resistance Tester (SRT) Pendulum which is widely used on roads field as a reference. The friction coefficient measured with this device is highly dependent on the microtexture of the surface.

Y. Hichri et al. performed a laboratory study by using a sandblasted aluminium slab covered by particles which simulates a contaminated road surface. Within the scope of their experimental design, these authors have noticed a reduced effect of the concentration of particles. After successive friction runs, it was shown that surface covered by coarse particles (more than 80 μm in size) tends to recover rapidly the clean-state friction level whereas very fine particles (less than 40 μm in size) keep the friction coefficient lower than that the one of a clean surface.

The above studies are focused on macroscopic observations of friction values. To understand the variations of friction and finally propose an explanatory model, it is necessary to go deeper into involved mechanisms by making microscopic observations. Thus, previous works dealing with rail/wheel contact both in laboratory and in-situ demonstrated through Scanning Electron Microscope (SEM) observation the appearance of a film acting as a lubricant in the contact area. Depending on the size and the type of particles, several mechanisms like rolling, scratching or crushing were observed [15–19] and the characteristics and the rheological behaviour of this film evolves. The transferability of these observations to roads field is questionable due to the difference of operating conditions (speed, load, contact pressure).

The aim of this paper is to bring to light the different particles behaviours during a friction measurement in dry condition to explain their effects on the lubrication of the tyre/road contact. Firstly, particles are characterised, then the movements of particles are observed as well as the mechanical behaviour of the types of particles at the interface.

2. Materials and methods

As explained previously, SRT pendulum was used to measure friction values. Observations of particles were performed during friction tests or after through different devices as a high-speed camera, a focus-variation microscope Alicona and a scanning electron microscope. Furthermore, several types of particles were used, two natural particles and glass spheres, to better understand mechanisms.

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[*] Corresponding author.
E-mail address: simonchangarnier@gmail.com (S. Changarnier).

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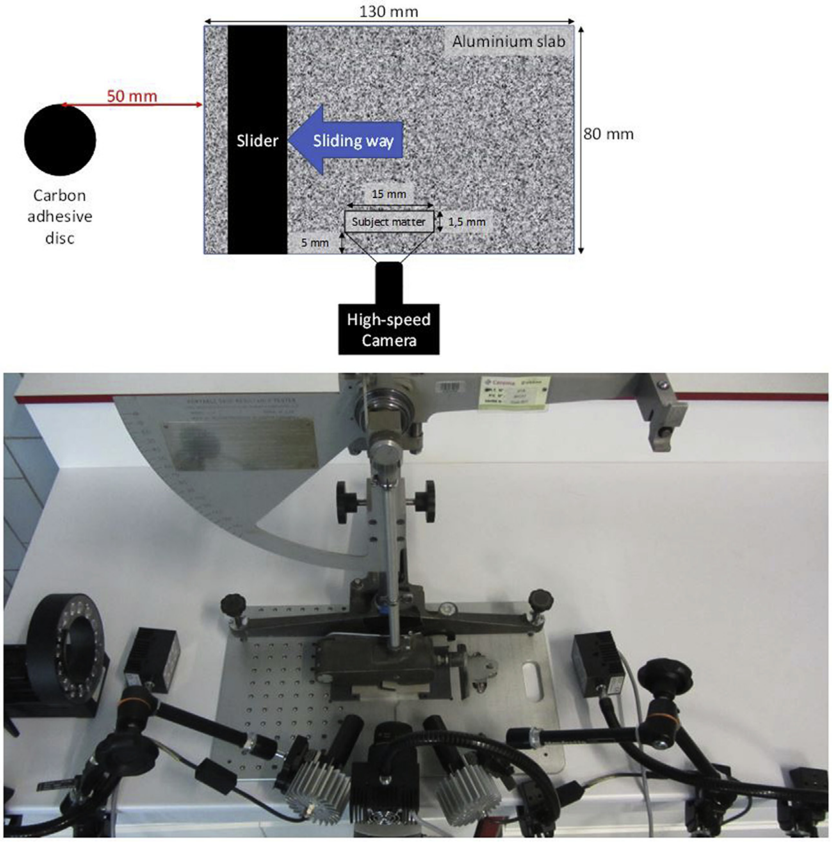

Fig. 1. Test rig.

2.1. Particles

2.1.1. Natural particles

Natural particles are collected from two sites. The first site, named "Cheviré", is a catchment area near the Cheviré Bridge in Nantes as presented in Y. Hichri et al. [14]. The second site, named "Savenay", is a drain on a hard shoulder from the freeway linking Nantes to Saint-Nazaire (GPS coordinate: 47.363300, −1.903233). Sediments are extracted from sites then dried and sieved in the laboratory. The protocol is described in Y. Hichri et al. [14]. It is assumed that the collected particles are equivalent to those present on roads.

Granulometries were determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). Chemical elements were determined by NF EN 12880, NF EN 18879, NF X31-147, NF EN ISO 11885 and an internal method of alkaline molten.

2.1.2. Glass spheres

Standardised glass spheres (NF EN 13036-1) of 180–250 μm in diameter are employed to compare their behaviours to natural particles ones, through the high-speed camera. It was necessary to employ relatively big model particles. Indeed, natural particles are too small to view their behaviour through the high-speed camera. Furthermore, natural particles are composed of particles of different nature and it is complicated to identify them and to distinguish their behaviours. Lastly, as glass spheres are chemically inert, it is possible to assess only to mechanical behaviours of particles without chemical interactions.

To identify glass sphere behaviours, as it was difficult to distinguish one sphere from another with a random spreading, it was decided to put one sphere by centimetre square in area of the slab surface. This unit (1 cm^2) is chosen because it represents the area of one aggregate.

As spheres being small, it is tough to drop one sphere off every centimetre square, the best way found to spread spheres regularly is to use a sieve having meshes of 165 μm in which holes were enlarged at a regular distance thanks to a standardised penetration needle (NF EN 1426). When glass spheres are spread on the holed sieve, only one sphere by hole is dropped off on the slab placed underneath the sieve.

2.2. Test protocol

2.2.1. Friction measurement

The same testing procedure as the one of Y. Hichri et al. [14] was followed. Friction was measured on a clean and dry aluminium slab, as indeed Y. Hichri et al. [13] showed, roughness parameters of the aluminium slab are similar to road aggregates polished by the traffic. The friction was measured after the deposit of particles, then the measurement of friction was repeated until stabilisation of the friction coefficient. Different fractions of particles (0–40, 40–50, 50–80, 80–100 and 0–100 μm) and concentration (10, 20 and 40 g/m^2) were tested with natural particles.

The friction slider of the SRT pendulum is made of rubber and rubs a sandblasted aluminium slab being 130 by 80 mm. The friction slider represents a tread block of a tyre. The sandblasted aluminium slab has a microtexture similar to polished aggregate. As microtexture is one main parameter having an impact on friction, it is essential to use a representative surface [20]. During friction tests, carbon adhesive discs were placed after the aluminium slab to collect ejected particles and a high-speed camera recorded the passes of the rubber slider (Fig. 1).

2.2.2. Material for observations of particles behaviours

2.2.2.1. High-speed camera. During friction measurement, the passage of the rubber over the slab was recorded by means of a high-speed camera. This enables to view particle movements. The body of the camera is a Motion BLITZ Cube4 and the lens is a Sigma 105 mm 1:2,8 DG MACRO. It was necessary to light up as much as possible the subject matter to take distinct pictures of particles. Parameters were optimised as follows to have the clearest pictures: