Tribology International 44 (2011) 437–444

Contents lists available at ScienceDirect

Tribology International

journal homepage: www.elsevier.com/locate/triboint

Friction and wear behavior of pure carbon strip sliding against copper contact wire under AC passage at high speeds

T. Ding, G.X. Chen *, X. Wang, M.H. Zhu, W.H. Zhang, W.X. Zhou

Tribology Research Institute, State Key Laboratory of Traction Power, Southwest Jiaotong University, Chengdu 610031, China

ARTICLE INFO

Article history:
Received 22 April 2010
Received in revised form
27 November 2010
Accepted 30 November 2010
Available online 10 December 2010

Keywords:
Friction
Wear
Dark stream-lines
Arc erosion

ABSTRACT

A series of tests on the friction and wear behaviour of pure carbon strip/copper contact wire with alternating current were conducted on a ring-on-block sliding tester at a high speed. The electric current, normal force and sliding velocity have distinct effects on the test results. The worn scar has the smallest size without electric current. The worn scar becomes larger with increasing electric current. Arc ablation pits, dark stream-lines of arc ablation, slipping marks, spalling blocks and the copper-like layer are found on the worn surfaces. Arc erosion, abrasive wear and adhesive wear are main wear mechanisms.

1. Introduction

In high speed railway operations, particular attention is given to the contact between the pantograph and catenary because the contact is essential to regular running of trains. With a fast development of high-speed electrified railways, high-speed running of trains will result in severer wear of the collector strips/contact wires in pantograph-catenary systems, which can affect the service life of the collector strip/contact wire materials. In the literature, numerous research studies were carried out to reduce the wear levels of pantograph-catenary systems and consequently the life cycle costs [1–3]. To date, however, severe wear of the collector strip is still a concern to investigators and operators. On the Beijing–Tianjing high speed railway line, severe wear of the collector strip was encountered. The severe wear will bring a high maintenance cost. Therefore, it is very important to study friction and wear behaviour of collector strip/contact wire materials used in high-speed electrified railway lines. So far, studies on friction and wear properties of collector strip/contact wire materials with electric current were performed mainly in small scale conditions. Most of the studies dealt with friction and wear behaviour of electric contact material at low speeds under the conditions of low DC and low normal forces [3,4–11]. Less effort was made on the basic friction and wear behaviour of electric contact materials at a high sliding velocity with a large AC. According to the authors' experience, a small scale test on electrical contact materials may lead to excessive wear of a collector strip material, which is larger than the practical result in the field due to severe arc discharge.

In the present work, a large scale tester is developed and used to study the friction and wear behaviour of electric contact materials. This paper presents some test results. Some discussion is also given, which is mainly based on observations and analyses of the worn scars and some interfacial phenomena occurring during testing.

2. Test equipment and procedures

2.1. Test machine

In the present work, a ring-on-block tester shown in Fig. 1 was developed for the present test purpose. The test machine mainly consists of a construction frame, a rotational disc, a collector strip frame, an AC power supply and a control console. The rotational disc is driven by a variable-frequency motor of 58 kW. A contact wire used in electrified railways is assembled on the outer edge of the disc. A full-scale collector strip whose length is 135 mm long is assembled on the collector strip frame. During testing, the collector strip frame can oscillate at an amplitude of 60 mm and at a frequency of 0.3–3 Hz in the vertical direction to partly simulate Z arrangements of the contact wires of electrified railways on the horizontal plane. The collector strip frame is driven by an electric servo actuator to provide a steady normal force between the collector strip and contact wire. The AC power supply can provide an electric power of 10–150 kW, a voltage of 100–3000 V and an electric current of 10–800 A. The sliding velocity of the disc with respect to the collector strip is ranged from 0 to 400 km/h. The normal force between the collector strip and contact wire ranges from 10 to 300 N.

* Corresponding author. Tel.: +86 28 87634122; fax: +86 28 87634122.
E-mail address: chen_guangx@163.com (G.X. Chen).

0301-679X/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.triboint.2010.11.022

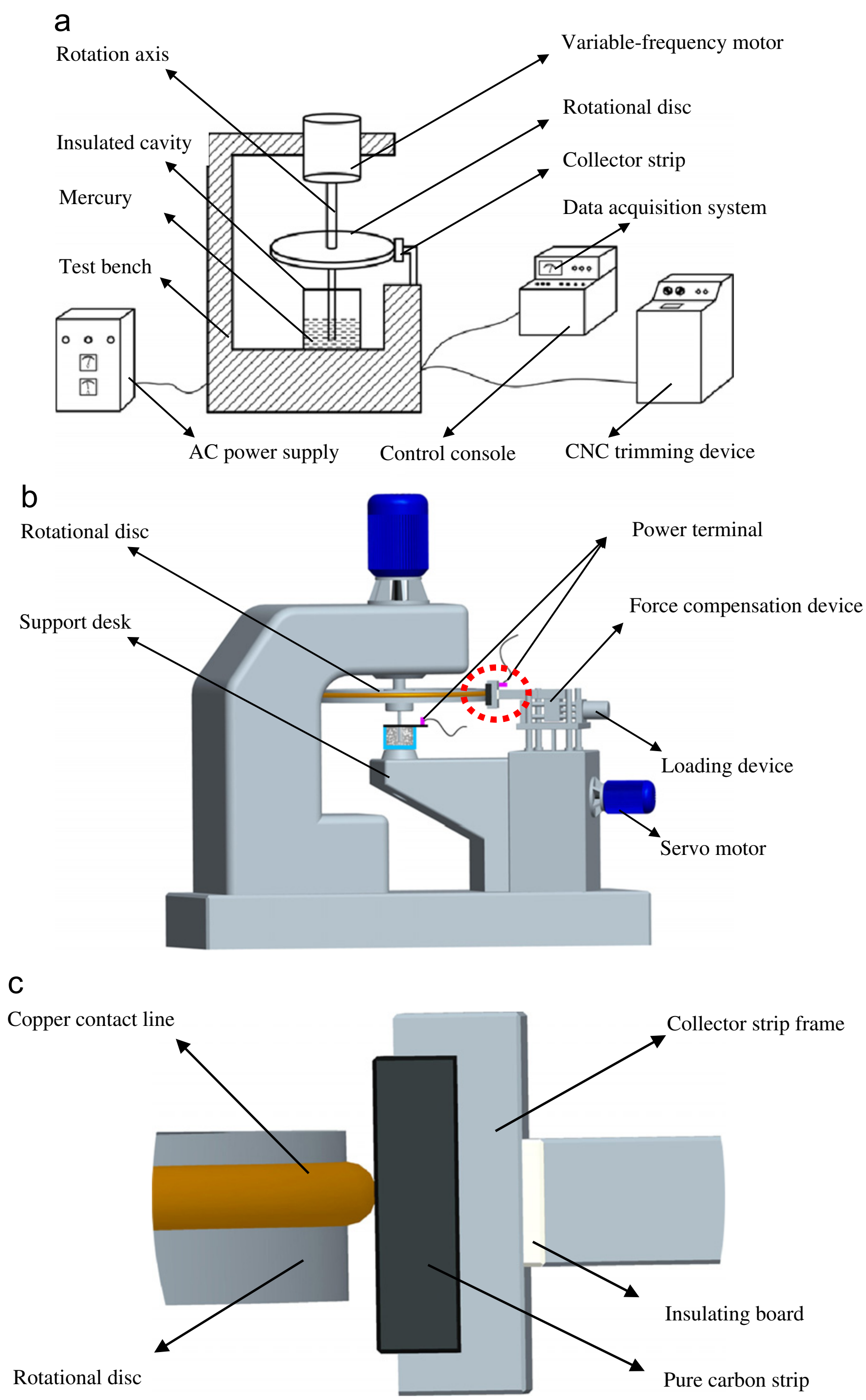

Fig. 1. Test machine: (a) scheme of the tester, (b) test machine, and (c) copper contact wire/carbon strip friction couple.

2.2. Test materials

Pure carbon strip and pure copper contact wire currently used in high-speed railways were chosen as test materials. The pure carbon strip is machined into a rectangular-shaped block of 135 mm × 34 mm × 25 mm. Its chemical composition (wt%) mainly includes 99% carbon and 0.1% microelements as well as impurities. The chemical composition of the copper contact wire (wt%) mainly includes 99.9% copper and 0.1% microelements as well as impurities. The contact wire was bent into a circular ring with a diameter of 1100 mm and embedded into an annular groove of the rotational disc without joint.

2.3. Test parameters and test procedures

The test parameters are set as follows. The electric current is set to $I=0$, 160, 180, 200, 220 and 240 A. The tangential speed of the rotational disc is set as $v=140$, 150, 160 and 170 km/h. The normal force is set as $F_n=60$, 90, 120 and 150 N. The sliding distance of the contact wire relative to the collector strip is chosen as $S=150$ km. For the vertical reciprocating movement of the pure carbon strip, the frequency and sliding stroke are set to $f=1$ Hz and A=110 mm, respectively. In order to measure the wear volume of the pure carbon collector strip, an electronic balance with an accuracy of 0.1 mg is used. A digital camera is used to take pictures of the worn