Mechanical Systems and Signal Processing 110 (2018) 110–121

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

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

Interaction between contact behaviour and vibrational response for dry contact system

Davide Tonazzi [a,b,*], Francesco Massi [a], Laurent Baillet [c], Jacopo Brunetti [d], Yves Berthier [b]

[a] DIMA, Department of Mechanical and Aerospace Engineering, "La Sapienza" University of Rome, via Eudossiana 18, 00184 Rome, Italy
[b] LaMCoS, Contacts and Structural Mechanics Laboratory, Université de Lyon, CNRS, INSA Lyon, UMR 5259, 20 rue des Sciences, F-69621 Villeurbanne, France
[c] Grenoble Alpes University, CNRS, IRD, IFSTTAR, ISTerre, 38000 Grenoble, France
[d] DIIIE, Department of Industrial Engineering Information and Economy, Università degli Studi dell'Aquila, Via G. Gronchi 18, I-67100 L'Aquila, Italy

ARTICLE INFO

Article history:
Received 20 September 2017
Received in revised form 22 December 2017
Accepted 9 March 2018

Keywords:
Frictional scenarios
Stick–slip instability
Mode coupling instability
Contact behaviour
Contact roughness

ABSTRACT

This work wants to provide insights on the coupling between contact behaviour (local scale) and vibrational response (global scale) which brings to different contact scenarios arising in dry frictional systems. A newer setup, named TriboWave, has been developed in order to reproduce and investigate the system response to frictional contact, under well-controlled boundary conditions. The experimental results highlighted how a simple frictional system can switch from stable friction-induced vibrations to unstable vibrations, i.e. either macroscopic stick–slip instabilities or mode coupling instabilities. The effect of the contact surface roughness on the reproduced frictional scenario has been investigated too.

1. Introduction

The frictional contact dynamics is an old and relevant issue in different disciplines as tribology, earth science, vibrational mechanics or fracture mechanics. A first important contribution to the understanding of dry friction was achieved by Leonardo da Vinci (1495) by introducing the terms of friction coefficient. A few centuries later, Amontons [1] and Coulomb [2] formalized the concept of friction between solid bodies in relation to contact material pairs, surface composition, lubrication, humidity and temperature.

In the last decades, the development of experimental and numerical simulation methods for investigating frictional phenomena have produced a sudden growth in the number of research activities considering not only the contact aspects but also the response of the system to which the contact surfaces belong. Godet [3] and Berthier [4] introduced the "third body concept" into the study of frictional phenomena leading to the notation of the "Tribological Triplet" [5]. This approach highlights how the contact between two frictional surfaces is influenced by the third body, which can be a solid, liquid or gas film interposed between the contact interfaces during sliding, by the response of the solids in contact and by the mechanism (dynamics of the system); thus the analysis of contact issues involves the interaction of various phenomena at different scales.

* Corresponding author at: DIMA, Department of Mechanical and Aerospace Engineering, "La Sapienza" University of Rome, via Eudossiana 18, 00184 Rome, Italy.

E-mail addresses: davide.tonazzi@uniroma1.it (D. Tonazzi), francesco.massi@uniroma1.it (F. Massi), laurent.baillet@univ-grenoble-alpes.fr (L. Baillet), jacopo.brunetti@univaq.it (J. Brunetti), yves.berthier@insa-lyon.fr (Y. Berthier).

https://doi.org/10.1016/j.ymssp.2018.03.020
0888-3270/

Furthermore, understanding the physical mechanisms involving the coupling between local (contact scale) and system (structure scale) dynamics during frictional relative motion is of great importance to many research and industrial applications. These mechanisms, related to both the contact and structure scales, can compromise the proper functioning of systems with frictional interfaces [6]. Many recent papers dealt with specific issues of complex systems, like brake squeal [7–11], instability of clutch discs [12], joint fretting [13], earthquake faults [14], tactile perception [15], or hip endoprosthesis squeaking [16–18], in order to control or predict the effects of the friction-induced vibrations in each particular case. Many papers in different domains have been dedicated to study the instabilities of systems excited by frictional contacts, following approaches focused either at the contact scale [6] (interface waves and rupture fronts [19–21], precursors [22,23], wear and third body [24]) or at the global response of the system (unstable modes [25], induced vibrations [26], macroscopic stick–slip [27–29]). A general approach, allowing for reproducing and investigating different kinds of frictional scenarios, as a function of the system parameters, is the object of this work.

In this context, the different frictional contact instabilities are here reproduced experimentally, when two elastic media are put in relative motion. In the following of the numerical and experimental results presented in [27,28], the present work focuses on the analysis of the dynamic response of the frictional system during the unstable contact vibrations; moreover, the influence of the contact interface roughness on the trend of the macroscopic frictional coefficient and, consequently, on the frictional scenarios is investigated. This work, together with previous numerical analyses [27], wants to provide insights on how the coupling between local (contact) behaviour and global (system) dynamics is at the origin of the different contact scenarios arising in any frictional system.

2. Experimental tools

2.1. Test bench: tribowave

A newer experimental tribometer has been designed and developed at the LaMCoS laboratory, in order to reproduce and investigate the system response and the contact behaviour of two bodies in relative motion. This setup allows for imposing a given driving displacement or velocity between the elastic bodies in contact (constant, sinusoidal, etc.), under an imposed normal load. More in general, the experimental setup has been designed for examining the contact and system response for different geometries, imposed loads and velocities, contact surfaces and materials in contact.

The study of instabilities occurring during frictional contact involves difficulties related mainly to the fast and high frequencies contact phenomena and their interaction with the system dynamics. In this context, the test bench has been designed to ensure the measurement reproducibility and to limit the noise and parasitic vibrations. The control and structure of the machine has been designed and developed in order to impose boundary conditions in a large range of the controlled parameters (normal load, imposed driving velocity, etc.), avoiding artificial contact scenarios. A more detailed description of the whole setup is presented in [30].

The imposed velocity, the macroscopic frictional forces (tangential and normal) and the system structural response (acceleration and velocity) can be measured accurately during the relative motion.

The setup has been instrumented with the following measurement devices in order to perform the experimental analysis presented in this paper:

- A 3D piezoelectric force transducer allows for recording the macroscopic normal and tangential force time histories and, consequently, the global response of the frictional system in a frequency range up to 20 kHz (see Fig. 1).

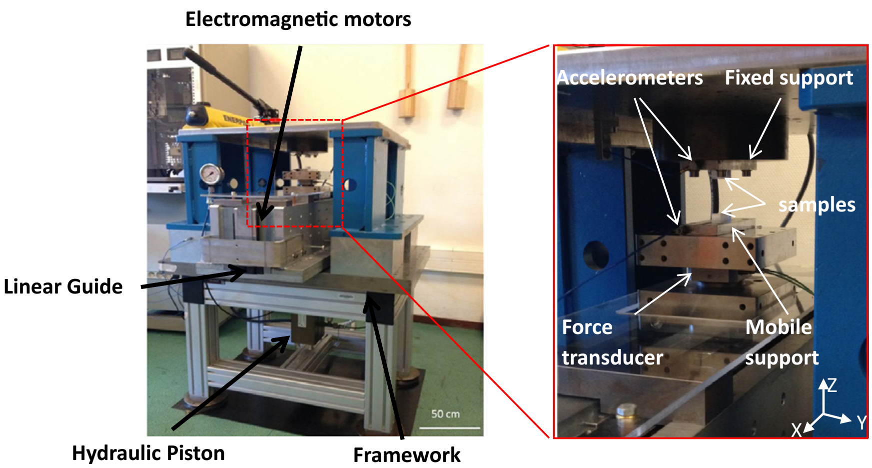

Fig. 1. Photograph of the experimental setup (TriboWave) and zoom related to the measurement zone.