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Introducing TRIBO

A new code for designing the tribological properties of surfaces from University of Trento

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In recent years, an emerging area in the field of Tribology with a greater focus on the environment has attracted the attention of researchers worldwide. It is known as 'green tribology' and is a way of making tribology environmentally friendly and energy-saving. It deals with interacting surfaces in relative motion and takes energy/environmental sustainability into consideration. At the same time, modern surface modification techniques are developing with the ability to adjust the tribological properties of contact surfaces, which opens up a new need for optimal tribological designs.

This article briefly introduces the new computer code, TRIBO that was developed in our research group to predict the tribological properties of contact surfaces and has the capability of considering a wide variety of surface modifications including complex surface patterning and heterogeneity of composites with a combination of statistically based adhesion and friction properties.

It is based on the lattice-spring method which has been successfully applied for many years in our research group for simulating various practical multi-scale studies such as the friction tuning of laser micro-textured surfaces, the tribology of hierarchical composites, the friction tuning of surfaces with functionally graded changes in properties, and tribology studies on 2D nano-material coatings at the nanoscale. With its flexible user-friendly interface, TRIBO is well-suited for use in industrial problems for tuning and optimizing the performance of sliding surfaces. This makes it thus the first program developed specifically for solving industrial tribological problems.

Introduction

Macroscopic tribological properties are the result of various types of complex multiscale interactions between sliding surfaces. There is considerable scope for fine-tuning them using treatments that can purposefully modify the surface structure, such as applying artificial patterning, and using heterogeneous composite surfaces and biologically inspired hierarchical patterns.

This section presents a brief overview of our recent studies in this field using lattice-based simulations and experimental validations. A 2D lattice-based model was proposed in [1, 2] to evaluate the effect of surface patterning using arrays of cavities and pillars on the frictional properties of elastic sliding surfaces.

An experimental and numerical investigation of the effect of surface patterning on the friction properties of polymer surfaces considering the effect of sliding velocity was conducted, and good agreement between the experiment and numerical simulation was observed [3].

A prediction of the frictional coefficients of composite hierarchical surfaces was performed in [4] and it was shown that a significant reduction in static friction can be achieved by introducing hierarchical arrangements with varying local roughness values, or by introducing controlled variations in material stiffness.

Using numerical simulations, [5] investigated how the properties of graded material influence macroscopic friction behaviour, in particular, static friction values and the transition from static to dynamic friction, and the results suggested that the properties of the graded material can reduce static friction, opening up possibilities for the design of bioinspired surface materials with tailored tribological properties. Following the model presented in [6], the effect of hierarchical surface patterning on the static and dynamic friction coefficients of an elastic material was studied using lattice-based numerical simulations, and several possible mechanisms were identified to explain how hierarchical structures may significantly alter the friction coefficients of materials, providing a means to achieve tunability [7].

As the contact of two surfaces in relative rotational motion occurs in many practical applications, from mechanical devices to human joints, more recently, the 2D lattice-based model has been extended to study the friction between surfaces in torsional contact [8]. How the model describes the behaviour of an elastic surface slowly rotating over a rigid substrate was studied, comparing the results with an analytical calculation based on energy conservation.

TRIBO Numerical Simulator

TRIBO is a home-grown code written as a MATLAB app. It is a general 3D lattice-based numerical simulator that predicts the tribological properties of contact surfaces by considering a wide variety of surface modifications including arbitrary complex surface patterning, heterogeneous composite surfaces, and graded mechanical and tribological properties with the option of combining adhesion and friction. It allows consideration of constant, ramp, and harmonic sliding velocity/force.

The main idea behind the TRIBO solver is to separate the sliders from the sliding blocks connected via a spring-damper

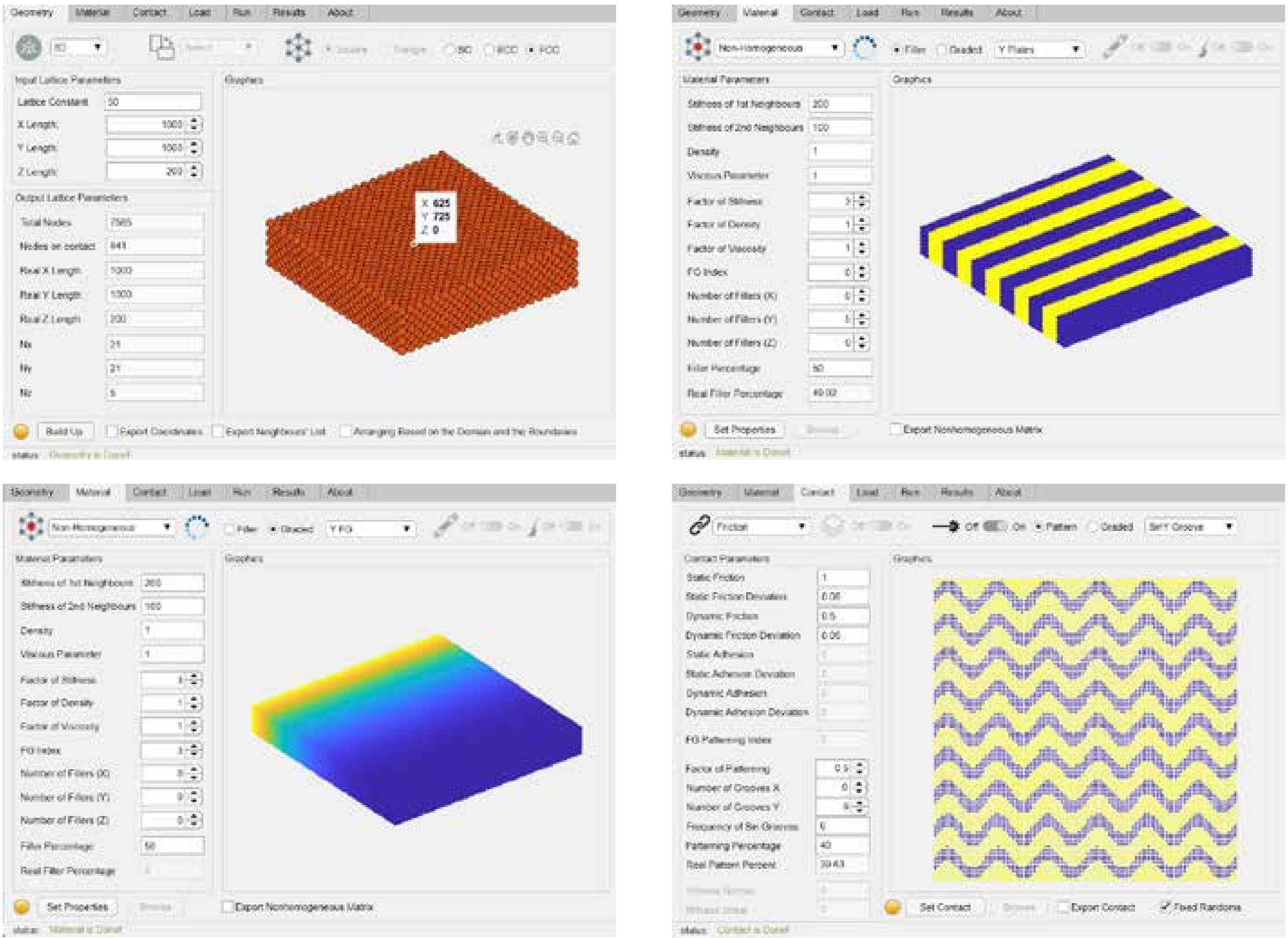

Fig. 1. Some samples of the TRIBO user interface for modelling homogeneous, composite, and functionally graded sliders with the option of defining complex surface modifications on the contact surface.

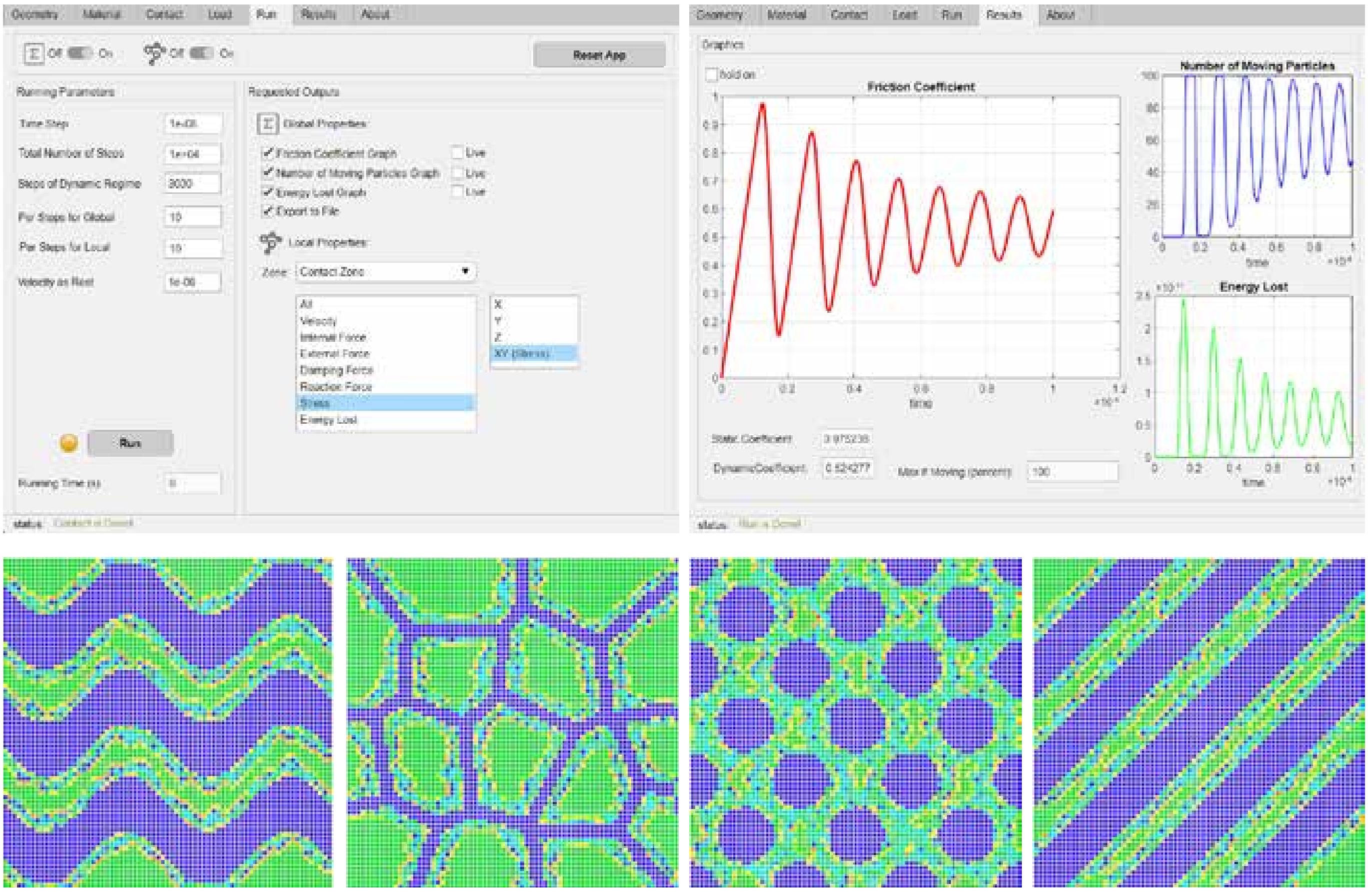

Fig. 2. Some global and local (per particle) TRIBO output samples.

network in which the spring and damper constants represent the mechanical properties of the material and the masses on the contact surfaces are also subject to the boundary reactions corresponding to the statistically distributed surface properties for each mass.

More details on the theoretical basis can be found in [1-8].
Fig. 1 presents examples of the TRIBO user interface for modelling sliders with a variety of material properties from composite to functional grade with the option of applying different surface modifications. Outputs are available for global properties such as macroscopic friction coefficients and lost frictional energy as well as for local properties (per particle), i.e. trajectories, velocities, forces, and stresses in the form of text data files compatible with well-known particle-based visualization software such as OVITO (see Fig. 2).

Conclusions

TRIBO is therefore the first program code developed specifically for solving industrial tribological problems and has already been implemented in the service of the industrial sector.

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