POLITECNICO
MILANO 1863

Postdoctoral Fellowship – Politecnico di Milano, Milan, Italy – 12 months

Supported by HORIZON-EIC-2021-PATHFINDEROPEN-01 (Project n. 101046693)

SSLiP: Scaling-up SuperLubricity into Persistence

Link to the call
https://www.polimi.it/en/faculty/working-at-the-politecnico/research-grants/a-r-default-2866a654d2
DEADLINE: February 21st, 2023

Scientific context
Friction between moving parts and the associated wear are estimated to be directly responsible for 25% of the world's energy consumption. SSLiP seeks to establish a radically new way to drastically reduce friction, with potentially enormous technological and societal impact. The driving concept is structural superlubricity, extremely low friction that takes place at a lattice misfit between clean, flat, rigid crystalline surfaces. Structural superlubricity is currently a lab curiosity limited to micrometer scale and laboratory times. SSLiP will bring this to the macroscale to impact real-life products. The key idea is the use of tribocolloids: colloidal particles coated in 2D materials, that will produce a dynamic network of superlubric contacts. Structural incompatibility between arrays of colloids allows to replicate the low friction on bigger length scales and overcome the statistical roughness of real surfaces. The superlubricious contact network will be realized through combination of counter-surface topography and interface-filling colloids of tuneable size and property distribution (Fig. 1).

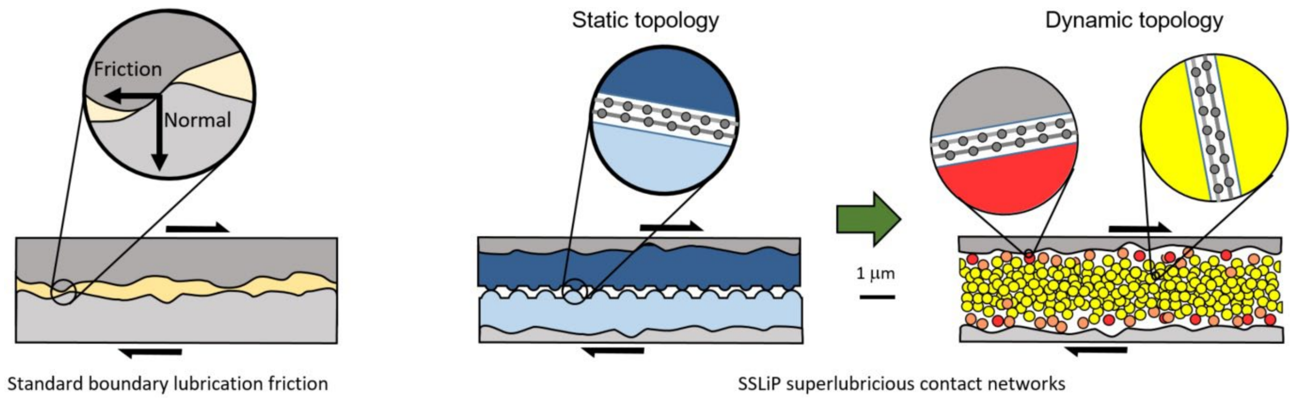

Fig. 1. Vision/Concept of SSLiP. Ploughing asperity contacts of standard boundary lubrication friction at rough surfaces are replaced by mesostructured tribocoatings (blue) and tribocolloids (yellow, orange) that define a load bearing lubrication system ranging from static, incommensurate topology counter-surfaces (middle) to a wholly dynamic topology of colloidfilled, native junctions (right).

It is crucial to understand how the superlubricious tribocolloids interact with each other, and how they behave collectively in a sliding interface with multiple contact asperities. To this purpose, SSLiP aims at leveraging advances in the field of granular matter that have revealed the nature of stress propagation in contact networks. In granular matter, dynamic networks of contact points formed between particles and structured surfaces are studied as a statistical mechanics problem to explain phenomena ranging from the emptying of grain hoppers and the flow of colloidal slurries to the collapse of river banks and snow avalanches. The latter operate via a highly localized defect mechanism known as an adiabatic shear band; the existence of which provides a key solution for SSLiP. The shear band is an emergent flow phenomenon ultimately arising from shear thinning that spontaneously localizes to a narrow planar region. While naturally arising in bulk disordered matter, recent simulations have shown that when shearing a tribological contact zone consisting of two rough counter-surfaces, if the gap is densely filled with a few diameters of frictionless particles with a low bulk coefficient of restitution, shear bands spontaneously form across the entire macroscopic contact zone greatly reducing shear resistance. Critical to this is the role of the rough surfaces, which serve to locally increase the granular temperature (reminiscent of the Leidenfrost effect when water drops hop across a hot pan) and create two extremely low shear resistance zones (shear bands) sandwiching a low temperature particle reservoir (quiescent condensed zone) that nevertheless maintain an overall normal load bearing capability as a lubricant (Fig. 2).

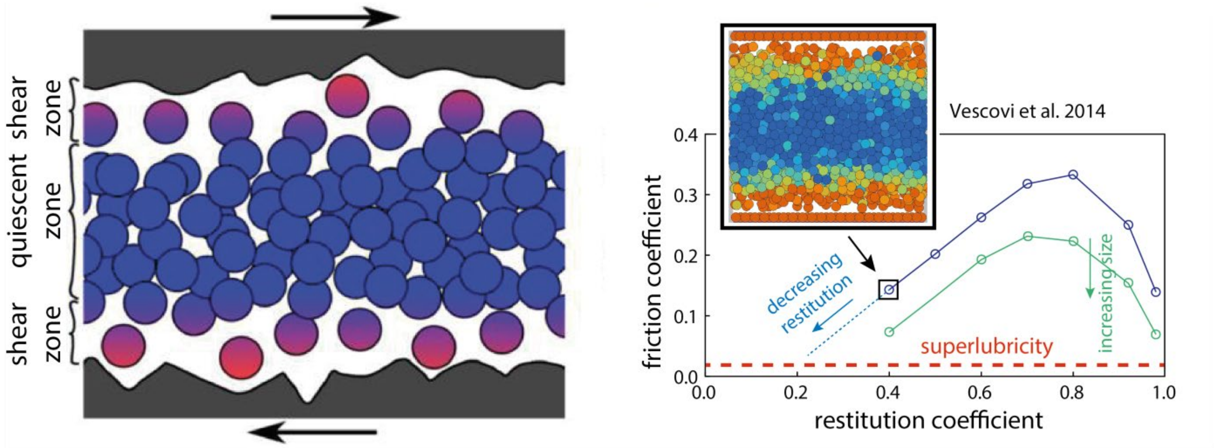

Fig. 2. **Towards superlubricity with SSLiP frictionless tribocolloids in a sliding rough interface.** Preliminary simulations show a quiescent condensed zone (cooled colloids, blue) sandwiched by emergent, hot boundary shear bands (red) (left). Tuning tribocolloid packing, density and contact restitution improves colloidal friction towards the superlubricious level (right). These key SSLiP insights provide promising physical mechanisms for superlubricity at colloidal scales.

Research objectives

To develop understanding of the restructuring of the network of superlubric contacts and the influence of the wide range of tuneable parameters, number of different types of molecular dynamics simulations will be performed. Simulations will be run with standard MD codes such as Mercury and LAMMPS which are well-optimised and include force fields for granular materials as well as Brownian dynamics. The description of the interactions between colloids will become more complex and realistic as the project progresses. The dependence of collective phenomena on tuneable interaction parameters will be studied: coefficient of restitution, surface topology, polydispersity, etc. This will allow to understand the basic mechanisms of the *quiescent condensed zone* and *boundary shear zones* (Fig. 2). In addition, the effect of the surface topology in multi-asperity superlubric sliding contacts with superlubric particles will be investigated.

Presentation of the Institute and of the Research group

Established in 1863, Politecnico di Milano (https://www.polimi.it/) is one the most outstanding technical universities in Europe, and the largest Italian university in Engineering, Architecture and Design, with over 45,000 students. The university has seven campuses located in Milan and in other nearby Italian cities: Lecco, Cremona, Mantova and Piacenza. It is organized in 12 Departments and in 4 Schools, respectively devoted to research and education. Politecnico di Milano offers innovative programmes at all academic levels. Almost the entire postgraduate academic offer is taught in English, thus attracting an ever-increasing number of international students, coming from more than 100 countries. The list of Politecnico di Milano notable Alumni is considerable and includes renown professionals, such as Renzo Piano and Aldo Rossi, both Pritzker and Prize winners, and Giulio Natta, Nobel Prize winner in Chemistry. Research plays a central role in the university mission, aiming at providing the best standards in education. It is fueled by strong links to corporate research, considerable European funds, and a set of well-equipped laboratories.

The SSLiP research group will be hosted by The Department of Civil and Environmental Engineering, which brings together professors and researchers involved in various research activities. The postdoc will take place in the Granular Mechanics team, whose activity concerns the kinematics and dynamics of granular materials and ranges from continuum modelling to numerical simulations to physical experiments (Fig. 3).

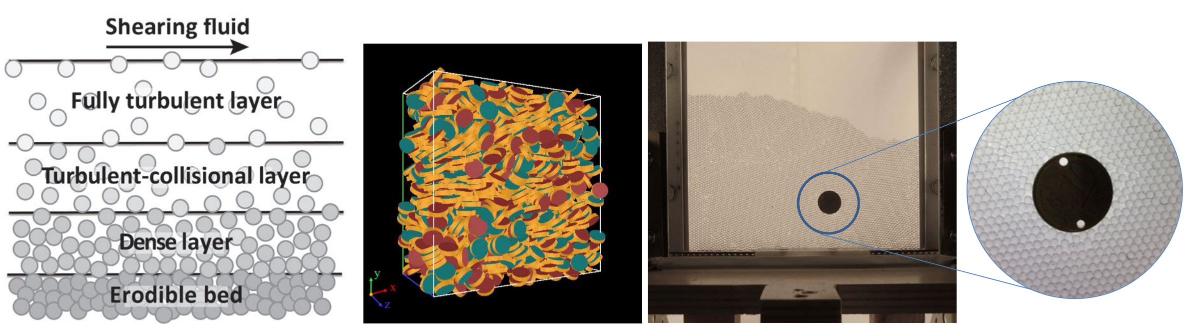

Fig. 3. Activity of the Granular Mechanics team

Associated researchers

The principal investigator is Prof. Diego Berzi, he will be supervising the postdoctoral researcher in collaboration with a number of internal and external scientific partners. Dr. Dalila Vescovi from Politecnico di Milano will help for the daily work. Prof. Astrid de Wijn from Norwegian University of Science and Technology (NTNU) will contribute on various scientific aspects of the project.

Requested training and experience

The recruited postdoctoral fellow will hold a PhD in one of these disciplines: Computational Mechanics, Mechanical/Mathematical/Civil Engineering, Granular Physics, Computer science, or Tribology.

He/She will be experienced in computational mechanics, especially on molecular dynamics simulations, and in data processing. He/she will also have a minimum track record in scientific publications, and an interest in granular physics/colloids.

Location, duration, starting date, salary

The work will mostly take place at Politecnico di Milano, in Milan, on the Leonardo Campus (https://goo.gl/maps/MiMTxRgk5w7RpWCM9), about 20 minutes from Milan City Center by public transportation (Fig. 4).

The Fellowship is for 12 months, starting around April 2023. Monthly salary is ~2.000 €.

Fig. 4. Views of Milan