Mechanical model of sliding friction and the study of the onset of sliding friction

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Abstract
The onset of sliding friction plays an important role, which represents the transition between static and dynamic friction. However, the underlying physical mechanism of this dynamic process is still unclear. Some studies have found that, a precursor in the form of a crack-like defect at the onset of sliding has been found in experiments, and this paper will further explore the physical nature of crack-like defects. We reduce the experimental configuration to a slider-substrate model. The interfacial force distribution obtained from the model is quantitatively consistent with the measured values, and can well describe the experimental results before the defect nucleation. By introducing a critical criterion for static dislocation nucleation, the calculated critical forces are in good agreement with those of the sliding precursor. The dynamics of the sliding precursor is further considered. We considered the dynamics of sliding precursors by solving the elastic problem due to a moving dislocation in a half plane and the transient emission of a dislocation at the edge. It has been found that both the strain field of a moving dislocation and the spatiotemporal evolution agree well with those of a sliding precursor detected in experiments. These works may contribute to further understanding of the mechanism related to sliding friction processes.

Introduction

Friction is common in our world. While it is well known that there exists the transition from static friction to dynamic one which marks the onset of sliding, how it takes place has not been thoroughly considered until Fineberg and his co-workers conducted a series of investigation. Through the work, many insights have been thrown. For instance, they detected the propagation of crack-like defects as the precursor for the overall sliding onset. By comparing the experimentally obtained strain field with that of a moving crack, good agreement has been found. The physical mechanisms underlying dynamics of the crack-like defects remain to be further ascertained because of some contradictions. To understand the nature of such crack-like defects, a reasonable model for the slider-on-substrate system may be desirable. Noticing that sliding onset may occur through nucleation of interfacial defects, an edge dislocation located at the interface will also be taken into account. Noting that dislocations under Peach-Koehler forces may move at high speeds, we would like to simulate the dynamics of the precursors for sliding onset by dislocations.

1. Results

a. We establish a model for the slender slider-substrate friction system. Agreement between the model results for our system with some available experiment results has been found, as shown in Fig.1.

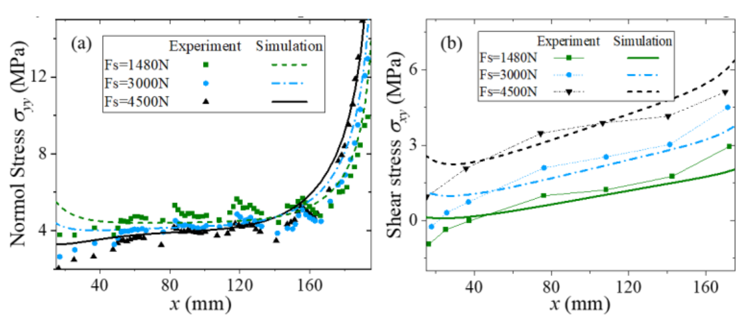

Fig.1. Comparison of interfacial stresses (a) normal stress; (b) shear stress between theoretical model and experiment under uniform load and shear force.

b. The possible defect is described by dislocation. Interfacial dislocation nucleation and mobility were also consistent with some features of sliding precursors.

c. Herein noting the precursor accompanied by relative sliding between the slider and the substrate, we would like to calculate the elastic fields due to a moving dislocation numerically.It can be seen from Fig.2 that agreement between the strain field of the dislocation and the experiments is very good.

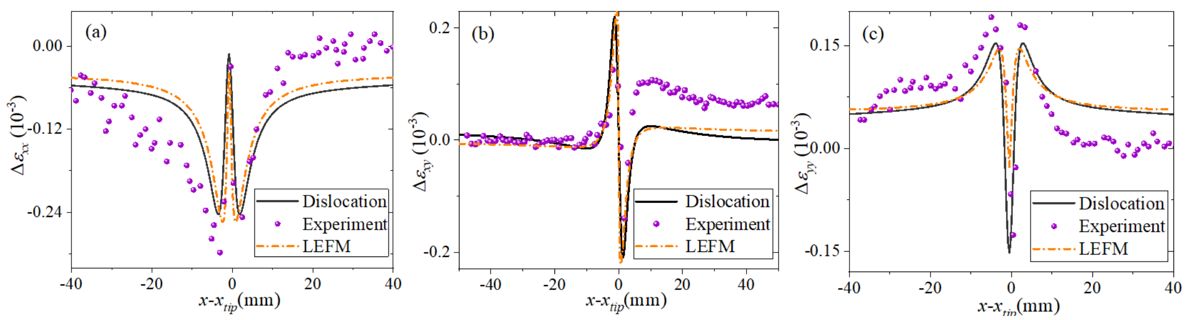

Fig.2. Compared solutions of elastic field (a) ; (b) ; (c) of the moving dislocation with the experiment's results and that of LEFM.

d. If one takes the slider as an elastic strip of finite length boned to a half plane as considered in, the stress field on the interface is identical to that of a crack of mode II provided the applied force is exerted along the strip at one end. Accordingly motion of the dislocation is exactly the same as the transient emission at a crack tip of Mode II. By solving the equation of motion for the dislocation numerically, the spatiotemporal evolution can be tracked.

2. Conclusions

We reduce the experimental configuration to a slider-substrate model, where the slider can be described using thin long beams and the substrate is considered as an elastic half-space. In this way, the relevant displacement and stress field solutions can be obtained by solving Cauchy singular integral equations. The numerical results show that the interfacial force distribution obtained from the model is quantitatively consistent with the measured values, and can well describe the experimental results before the defect nucleation. Moreover, it can be seen from the results that the interfacial field is consistent with the elastic field of mode II crack. By introducing a critical criterion for static dislocation nucleation, the calculated critical forces are in good agreement with those of the sliding precursor.

Based on the model, the dynamics of the sliding precursor is further considered. That is, according to the consistency between the slide-substrate model and the mode II crack, we calculate the elastic field caused by the moving dislocation in half space, simulate the transient emission process of the dislocation at the tip of the mode II crack, and then explore the nature of the sliding initiation. It is found that the strain field caused by the moving dislocation is in good agreement with the strain field caused by the defect in the experiment, and the transient emission process of the interface edge dislocation is similar to the spatio-temporal dynamic behavior observed in the experiment, which indicates that the dislocation may also be the physical basis for the onset of sliding. These works may contribute to further understanding of the mechanism related to sliding friction processes.

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