Identification of the tangential contact stiffness from reciprocating sliding tests

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Abstract

Tangential contact stiffness is a critical parameter derived from reciprocating and fretting friction tests. However, the process for determining this stiffness from friction hysteresis loops lacks standardization and clear physical interpretation. It's usually defined as the slope in the stick phase assuming a linear relationship between the tangential friction force and displacement (1). This study aims at identifying the tangential contact stiffness from reciprocating sliding tests, by taking advantage of the Mindlin-Cattaneo solution for partial slip conditions. The identified contact stiffness during partial slip is represented by the ratio between the contact radius and the equivalent shear modulus of the material pair in contact. The proposed method is used to post-process the reciprocating friction test data between various wood species and bearing steel balls (E52100, a high carbon and a high chromium allow), measured under gradually changing normal force conditions. A tribometer was used to conduct the friction test between azobé (*Lophira alata*), European beech (*Fagus sylvatica*), spruce (*Picea abies*) and balsa (*Ochroma pyramidale*) wood blocks and a bearing steel sphere. In addition to the identification of tangential contact stiffness, a statistical picture of the identified coefficient of kinetic friction is also shown, by taking into account the influences of wood surfaces and sliding planes. The results demonstrate that the proposed method can effectively capture all the most representative parameters of the reciprocating sliding tests with changing normal forces. For validation purposes, the aforementioned results are also compared for tests carried out for a set of constant normal forces, and a fairly good qualitative agreement was found in terms of observed trends. A comparative study between the identified Cattaneo-Mindlin stiffness parameter and a more conventional method, based on directly extrapolating the tangential contact stiffness from the slope of the partial slip phase, highlights that the proposed method can be used to interpret the partial slip phase in reciprocating sliding tests.

Furthermore, in Ref (2), it was shown that the ratio between the contact radius and the equivalent shear modulus is equivalent to the stiffness parameter in the Dahl model. Thus, the identified Cattaneo-Mindlin stiffness parameter is then integrated into the Dahl and LuGre model, in order to reproduce the measured friction hysteresis loops. Results show that the friction hysteresis loops, measured under varying normal forces, can be reconstructed using the identified tangential contact stiffness and the coefficient of kinetic friction.

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Finally, few test cases during which squeal occurred after a surface degradation process will be shown. To interpret the squeal data, hammer tests and modal analysis are used, in order to extract the modal properties of the test-rig. Hence, the squeal occurrence is explained through a minimal mode-coupling and sprag-slip model, highlighting the relevance of the contact stiffness for the occurrence of friction-induced instability.

References

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