Reduced-Order Modeling Friction for Line Contact in a Turbine Blade Damper System

Reduced-order modelling friction contact for cylinder-flat contact and experimental validation in an under-platform damper

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Abstract. The aim of this work is to improve the representation of contact interfaces in modelling blade-damper systems. A new multi-scale nonlinear interface model is developed based on a modification of IWAN model considering non-uniform distribution of contact pressure at cylinder-flat surface. Experimental results about a laboratory asymmetrical under-platform damper are employed to validate the developed interface model. A dedicated contact parameter extraction procedure is devised to obtain friction coefficient and contact stiffness. Friction coefficient is determined by tangential over normal force ratio on surface, while the determination of contact stiffness is based on hysteresis loop matching with the numerical by the method of genetic algorithm. The results show that numerical simulation matches well with experimental results.

Introduction

To prevent high cycle fatigue failures due to resonant vibrations, under-platform damper are always used as a source of dry friction damping and included into turbines to dissipate vibration energy. Friction contact between blade and under-platform damper introduces nonlinearities in the system. Predicting energy dissipation of an under-platform damper is an important way to design the shape of damper. Therefore how to accurately describe friction contact behaviour at surface is a prerequisite for modelling a blade-damper system. Some developed interface models [1-3] assume that the contact pressure distribution is uniform, concave or convex, or do not consider the effect of this factor on interface behaviour. In this work, a new interface model considering non-uniform distribution of contact pressure is proposed. This model integrates Hertz-type contact theory into the IWAN model [4] which is widely used for modelling friction contact. The relation between tangential restoring force and tangential relative displacement is given. Furthermore, this model can be easily inserted into a blade-damper dynamic analysis model.

Method

Modelling friction contact

According to Hertz-type contact theory, non-uniform distribution of contact pressure is introduced into original IWAN model to represent friction contact behaviour at a cylinder-flat contact. First, in original IWAN model which does not consider normal load variation and possible separation, different contact pressure distributions (as shown in Figure 1) are studied and a non-uniform distribution IWAN is developed. Then, normal load variation and intermittent separation are integrated into the developed model to describe the coupling of tangential and normal contact behaviour. Equation (1) is the expression of tangential restoring force with relative displacement.

$$T(x)=\begin{cases}\dfrac{2\alpha\mu N_0}{\pi}\operatorname{atan}\sqrt{\dfrac{(\pi k_t x)^2}{(4\alpha\mu N_0)^2-(\pi k_t x)^2}}+\dfrac{k_t x}{8\alpha\mu N_0}\sqrt{(4\alpha\mu N_0)^2-(\pi k_t x)^2}, & 0<x<\dfrac{4\alpha\mu N_0}{\pi k_t},\\[2ex] \alpha\mu N_0, & x\geq\dfrac{4\alpha\mu N_0}{\pi k_t}.\end{cases} \tag{1}$$

where $T(x)$ is tangential restoring force, k_t is tangential contact stiffness, x is tangential relative displacement, μ is friction coefficient, N_0 is normal constant preload, α denotes normal load variation.

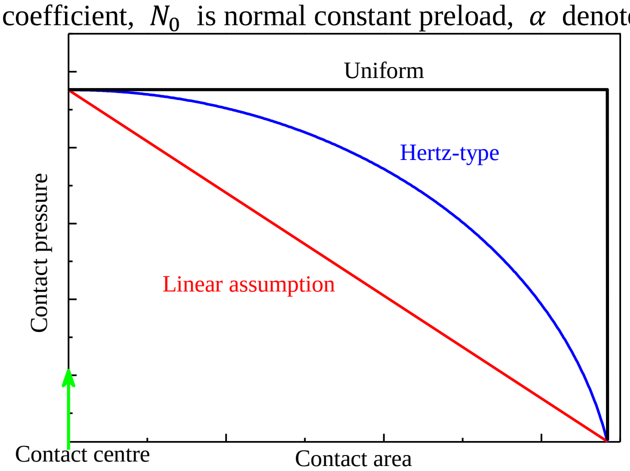

Figure 1: Contact pressure distribution

Experimental validation

In order to validate the developed model in a laboratory under-platform damper, a dedicated contact parameters estimation procedure is devised to extract friction coefficient and contact stiffness values. This approach is based on random sampling and mathematic relation among contact parameters in this special laboratory damper. Figure 2(a) illustrates a flow chart of the parameter estimation procedure. Figure 2(b and c) depict shape of the under-platform damper and 2D model of the experimental blade-damper system.

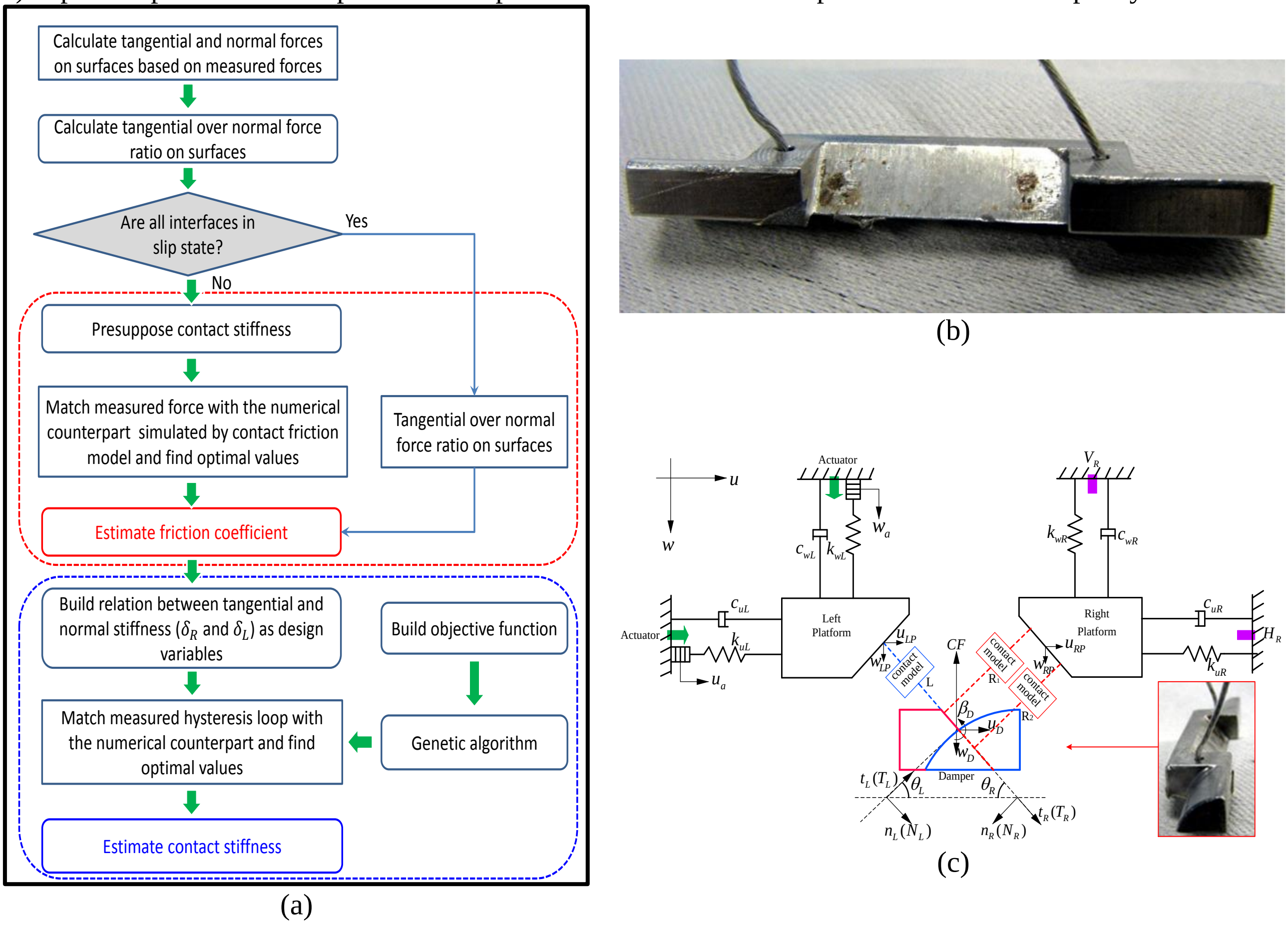

Figure 2: (a) flow chart of contact parameters estimation, (b) a laboratory crossed curve-flat under-platform damper, (c) 2D model of the under-platform damper

Results and Conclusions

Figure 3 illustrates hysteresis loops simulated by the developed model and obtained from experiments. The results show that numerical simulation matches well with experimental results. The developed contact parameters estimation approach and experimental results can be regarded as a benchmark for validating friction contact model.

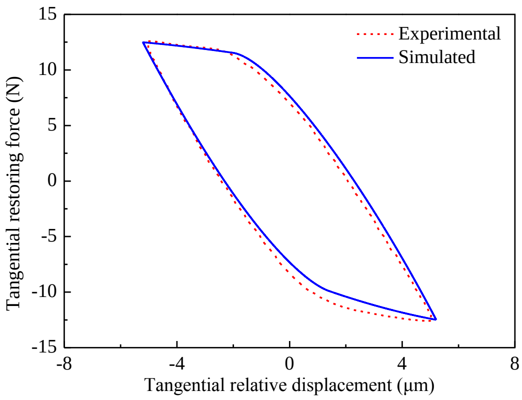

Figure 3: comparison between numerical simulation and experimental results

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