16th INTERNATIONAL CONFERENCE
Dynamical Systems – Theory and Applications
December 6-9, 2021, On-line

Modeling and simulation of friction processes with applications of piecewise-linear luz(…) and tar(…) projections

DĘBOWSKI ANDRZEJ[1] , ŻARDECKI DARIUSZ[2*]

1. Military University of Technology (WAT) [ORCID 0000-0003-1446-4415]
2. Military University of Technology (WAT) [ORCID 0000-0002-3934-2150]
* Presenting Author

Abstract: Modeling and simulation of systems with friction is still one of the most sophisticated problems of mechanics science, even it concerns "macroscopic" descriptions of friction actions in discrete MBS-type systems (Multi-Body Systems). Due to dry friction, such systems must function as systems with a variable structure resulting from stick-slip processes. The application of the Gauss principle enables to "circumvent" the problems of indeterminate forces of static friction in the states of total stiction. The use of luz(...) and tar(...) projections facilitates the synthesis of models in possibly compact forms. The article presents a "library" of ready-to-use mathematical models of several important elementary structures of MBS systems with friction that can be used in modeling of more complex mechanical systems. The created non-smooth models have no entangled forms, and are easy to use in computer programs with standard numerical procedures. The developed method can be used in the analysis of stick-slip phenomena in complex mechanical structures even in cases of static friction forces undetermined distribution. The article presents representative examples of the application of the method.

Keywords: systems with friction, stick-slip, modeling, simulation, projections.

1. Introduction

Two main categories of friction problems are noticed [3]: The first one concerns "microscopic" friction models and is representative for the tribology and contact theory. The second one concerns "macroscopic" descriptions of friction actions (stick-slip phenomena) in discrete systems and is representative for the MBS theory. Even though the macroscopic descriptions of the systems with friction based on Coulomb friction laws have a simplified character, a synthesis and analysis of such MBS models is usually very sophisticated [1]. Note, that even in 1D or 2D structures we can find peculiar problems (static friction force indeterminacy, Painleve paradoxes, etc.). In complex 3D MBS-type systems such problems are even more complicated. Modeling of discrete mechanical systems with friction must be supported by the mathematical theory relating to non-smooth dynamic systems, variable structure differential equations and inclusions [2]. Therefore in many cases simulation methods use iterative algorithms or heuristic procedures.

2. Results and Discussion

Meanwhile, as shown in the authorial works [4], [5], [6] a number of difficult problems of modeling friction systems can be resolved in a strict manner with using luz(…) and tar(…) piecewise linear projections (fig.1) and their mathematical apparatus.

Several friction systems discussed in that works have the variable structure analytical form of model (without algebraic constraints), ready to use in simulation programs with standard numerical procedures. Note that among these systems are the systems (for example two-mass system with three friction actions) with the problem of static friction indeterminacy resolved. Resolution of static friction indeterminacy and synthesis of variable structure differential equations of motions has been here possible thank to application of the Gauss rule (minimization of acceleration energy in total stiction).

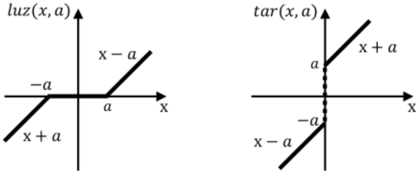

Fig. 1. Geometric interpretations of the luz(…) and tar(…) projections

The method of modeling and simulation friction processes with application luz(…) and tar(…) projections will be shown on the model of the system being activated on a special test stand. This stand is intended for very sophisticated experiments. It will be an instrument for verification elaborated models of elementary systems acting with friction in different mechanical configurations (fig.2).

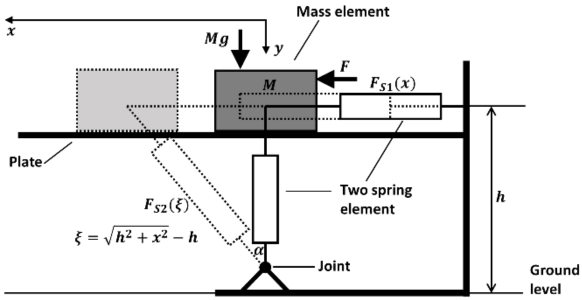

Fig. 2. Example configuration of the stand for testing friction processes

3. Concluding Remarks

The piecewise linear description basing on the luz(…) and tar(…) projections can be applied also for the friction characteristics expressing Stribeck effect, for characteristics with non-symmetry, etc.. Although the stick-slip models have been derived here for simplest friction characteristics, their final forms can be easy adapted to the other more complicate characteristics.

The luz(…) and tar(…) projections seem to be very efficient for modeling non-smooth mechanical systems.

References

[1] AWREJCEWICZ J., LAMMARQUE C.H.: Bifurcation and Chaos in Nonsmooth Mechanical Systems**.** World Scientific Publ. Co. Singapore, 2003.

[2] BROGLIATTO B., DAM A.A.T., PAOLI L., GENOT F., ABADIE M.: Numerical simulation of finite dimensional multibody nonsmooth mechanical systems. *Applied Mechanical Review*: 2002, **55**(2), 107-150.

[3] IBRAHIM R.A.: Friction-induced vibration, chatter, squeal, and chaos. Part I: Mechanics of contact and friction. Part II: Dynamics and modeling. *Applied Mechanical Review:* 1994**, 47**(7), 207-253.

[4] ŻARDECKI D.: Piecewise Linear luz(...) and tar(...) Projections. Part 1 – Theoretical Background, *Journal of Theoretical and Applied Mechanics*, 2006, **44** (1), 163-184.

[5] ŻARDECKI D.: Piecewise Linear Modeling of Friction and Stick-Slip Phenomenon in Discrete Dynamic Systems, *Journal of Theoretical and Applied Mechanics*, 2006, **44** (2), 255-277.

[6] ŻARDECKI D.: Static Friction Indeterminacy Problems and Stick-Slip Phenomenon Modeling in Discrete Dynamic Systems, *Journal of Theoretical and Applied Mechanics*, 2007, **45** (2), 289-310.