ViscoIndent Documentation

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April 2020

1 Introduction

ViscoIndent is a library written in the Python programming language for simulation of the force versus indentation curves of soft viscoelastic materials. The algorithm for the numerical simulation of curves was previously used and described in the works [1, 2, 3] and based on the numerical solution of the equations presented by Dr. T.C. Ting [4, 5].

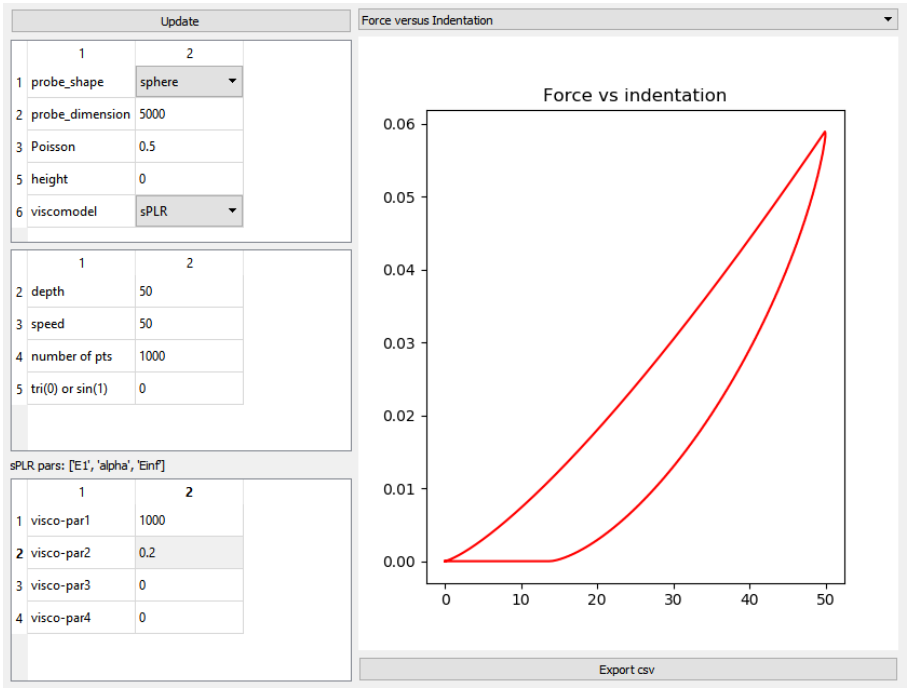

Figure 1: The graphical user interface

The graphical user interface (GUI) has following functionality:

1. “Update” button at the top left - press it to update the graph with the current parameters in the field below

2. Table with the general parameters. Probe shape: sphere, cone or cylinder. Probe dimension: radius for the sphere and cylinder (nm), half-opening angle for the cone (degrees). Poisson’s ratio of the sample. Height(thickness) of the sample (for the bottom effect correction). Viscoelastic model - select one of the models from the list.

3. Table with the parameters that define the indentation history. Maximum indentation depth (nm), speed (nm/s), number of points in curve, triangular (0) or sinusoidal (1) displacement.

4. Table with the viscoelastic parameters. The meaning of the parameters is presented in the text above the table (after the viscoelastic model is selected)

5. Top right - selector for the graph representation, the calculated force versus indentation or the force versus time. Press “update” button to apply the changes.

6. The graph with force versus indentation or force versus time curve.

7. “Export csv” button - exports current data into the .csv file in the same folder where the python files are located.

The main parameters are:

• “probe_shape” – currently available probe (tip) shapes are: sphere (Hertz model); cone (Sneddon model); cylinder;

• “probe_dimension” – probe radius in [nm] (for sphere/cylinder) or angle in [degrees] (for cone);

• “Poisson” – Poisson’s ratio of the sample;

• “height” – local height/thickness of the sample, if known, a value in [nm]. Leave “0” if it is assumed to be infinite. The model with bottom effect correction is currently available only for certain probe shapes in a test mode;

• “viscomodel” – viscoelastic model. Please see the description of the viscoelastic models in [1].

The indentation parameters are:

• “depth” – maximum indentation depth [nm];

• “speed” – indentation speed [nm/s];

• “number of pts” – number of points in curve;

• “tri(0) or sin(1)” – select between triangular (0) or sinusoidal (1) displacement profile.

2 To be continued

References

[1] Yuri Efremov, S.L. Kotova, and P.S. Timashev. Viscoelasticity in simple indentation-cycle experiments: a computational study. *bioRxiv*, 2020.

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[3] Yuri M. Efremov, Wen-Horng Wang, Shana D. Hardy, Robert L. Geahlen, and Arvind Raman. Measuring nanoscale viscoelastic parameters of cells directly from AFM force-displacement curves. *Scientific Reports*, 7(1):1541, 2017.

[4] T. C. T. Ting. Contact Problems in the Linear Theory of Viscoelasticity. *Journal of Applied Mechanics*, 35(1):248, 1968.

[5] T.C.T. Ting. The contact stresses between a rigid indenter and a viscoelastic half-space. *Journal of Applied Mechanics*, 33(4):845–854, 1966.