

Engineering Conferences International ECI Digital Archives

Nanomechanical Testing in Materials Research and
Development V

Proceedings

Fall 10-4-2015

Obtaining mechanical properties of superelastic materials from microindentation data

Dmitry Zhuk
NRNU, dimazhuk@gmail.com

Margarita Isaenkova
NRNU

Olga Krymskaya
NRNU

Yuriy Perlovich
NRNU

Follow this and additional works at: http://dc.engconfintl.org/nanomechtest_v

 Part of the [Materials Science and Engineering Commons](#)

Recommended Citation

[1] Yan, Wenyi, et al. "Determination of transformation stresses of shape memory alloy thin films: a method based on spherical indentation." *Applied physics letters* 88.24 (2006): 241912. [2] Kan, Qianhua, et al. "Oliver-Pharr indentation method in determining elastic moduli of shape memory alloys—A phase transformable material." *Journal of the Mechanics and Physics of Solids* 61.10 (2013): 2015-2033.

This Abstract and Presentation is brought to you for free and open access by the Proceedings at ECI Digital Archives. It has been accepted for inclusion in Nanomechanical Testing in Materials Research and Development V by an authorized administrator of ECI Digital Archives. For more information, please contact franco@bepress.com.



Obtaining mechanical properties of superelastic materials from microindentation data

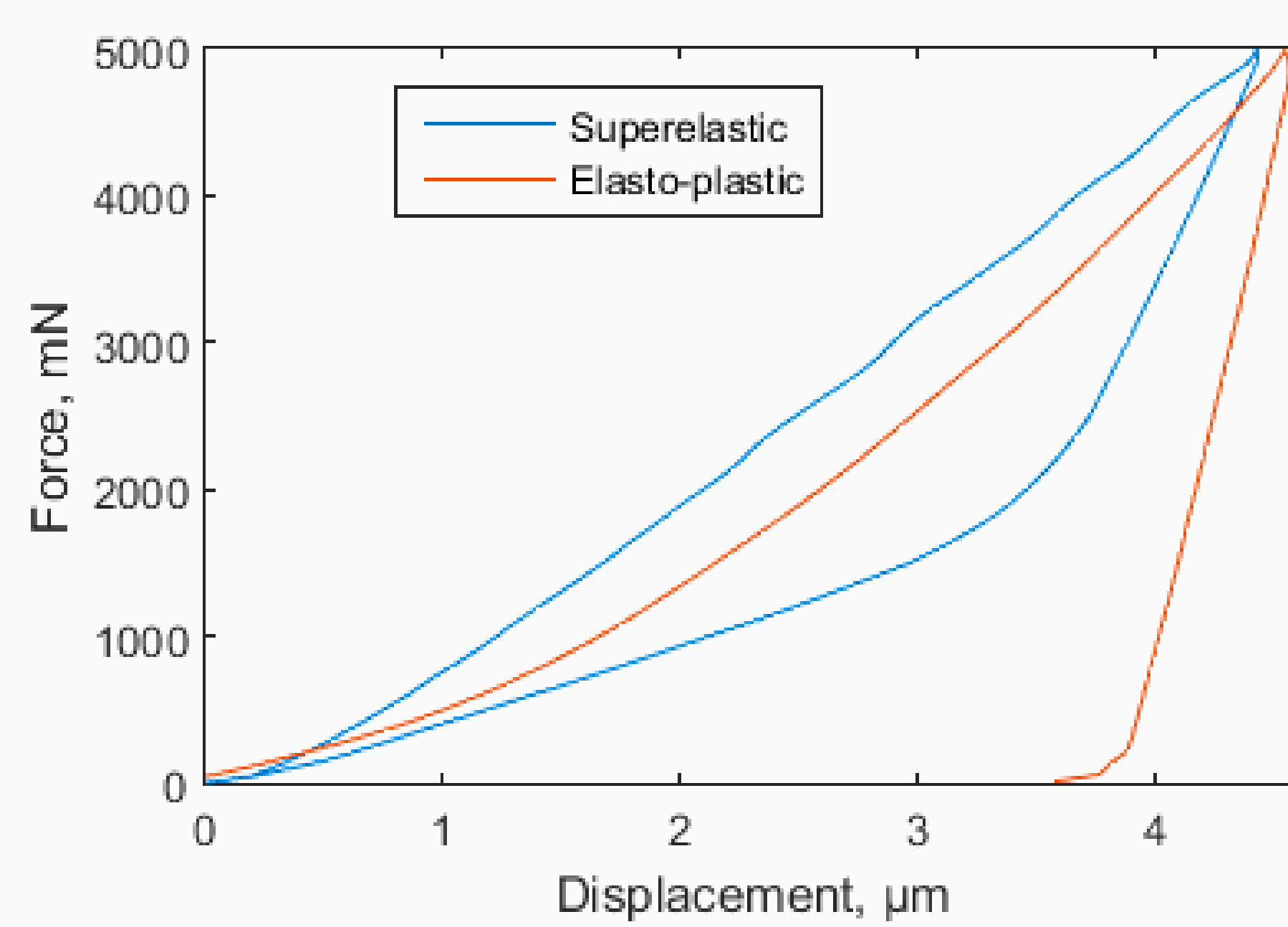
Yuriy Perlovich, Margarita Isaenkova,

Dmitry Zhuk, Olga Krymskaya

NRNU MEPhi, Moscow, Russia, dimazhuk@gmail.com

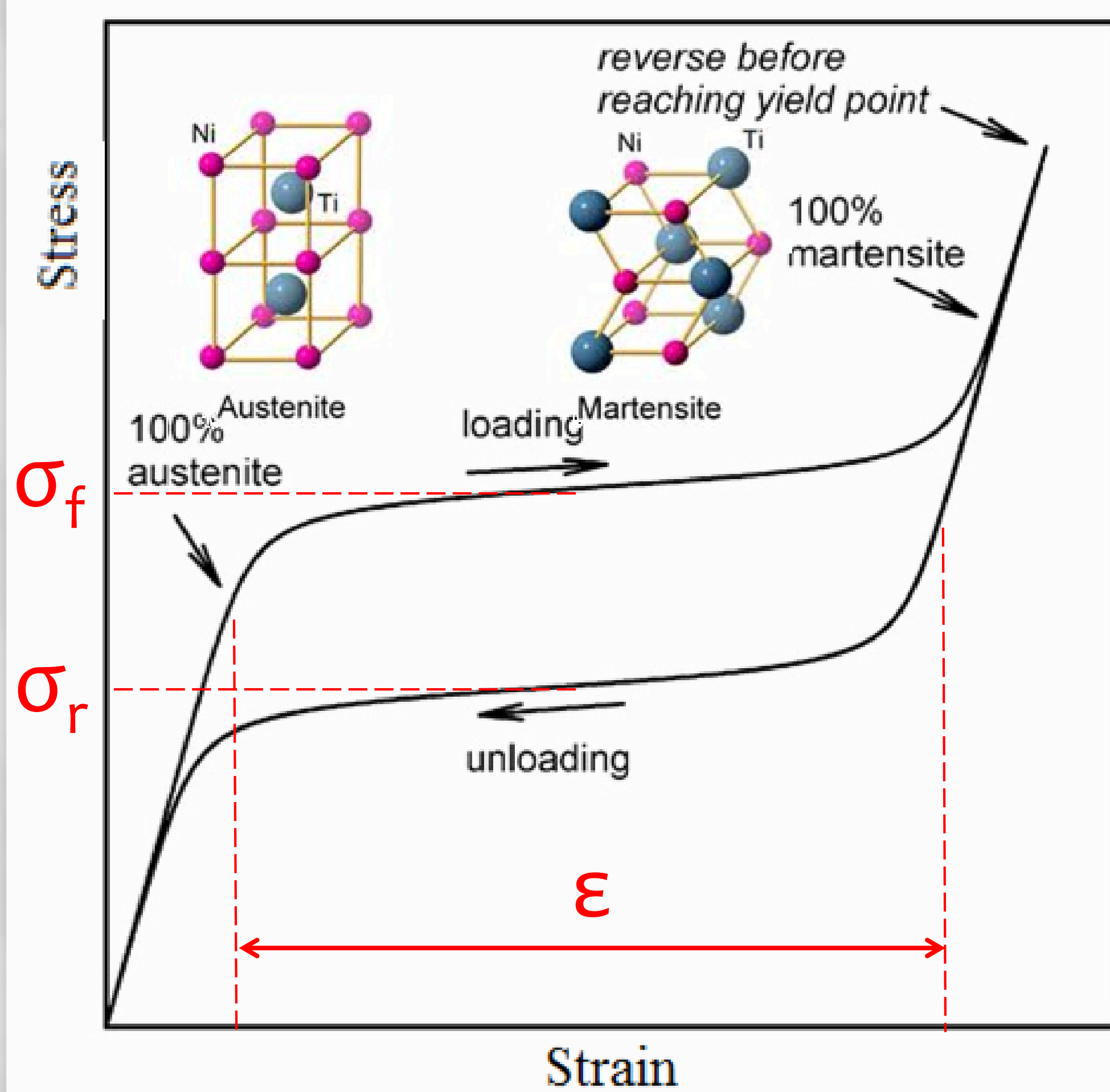
Introduction

This work is focused on indentation of superelastic (SE) materials with austenite - martensite phase transformation and extraction of material properties. Superelasticity includes two stages: (1) elastic deformation by ~0,2% due to interaction of neighboring atoms, (2) recoverable deformation by 2-9% and more due to martensitic transformations (MT). Finite element (FE) modeling was used to model indentation of superelastic alloys with spherical indenter. Several series of simulations were calculated with different elastic modulus of austenite and martensitic phases, stresses of phase transition in both directions. It is possible to create a method for determining mechanical characteristics of superelastic alloys using results of various materials' simulations.



Methods & Materials

SE materials can deform recoverably to a very high degrees, up to 10%. Phase transformation initiates when stress is higher than the transformation start stress and fully performed after stress is higher transformation finish stress.



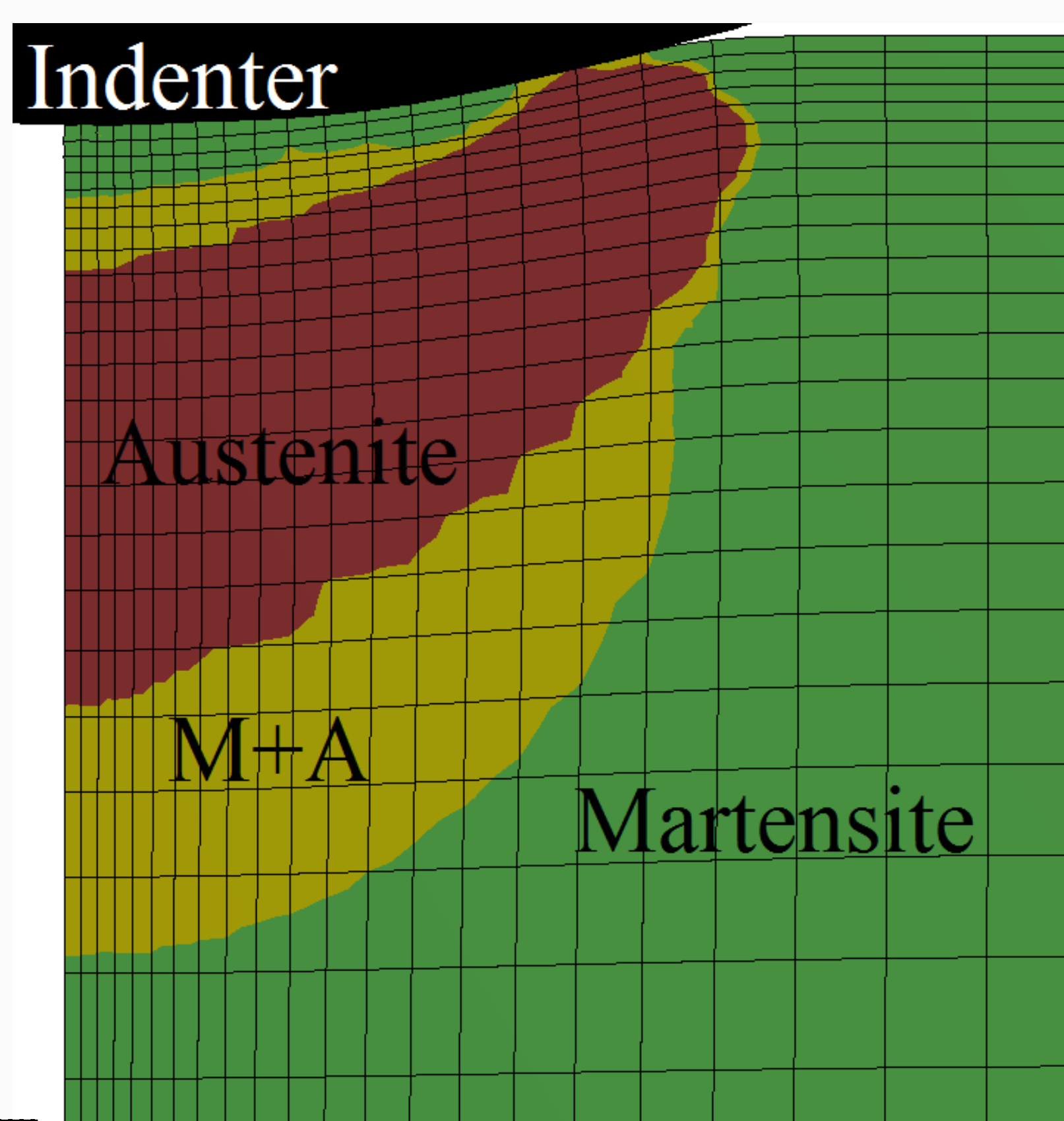
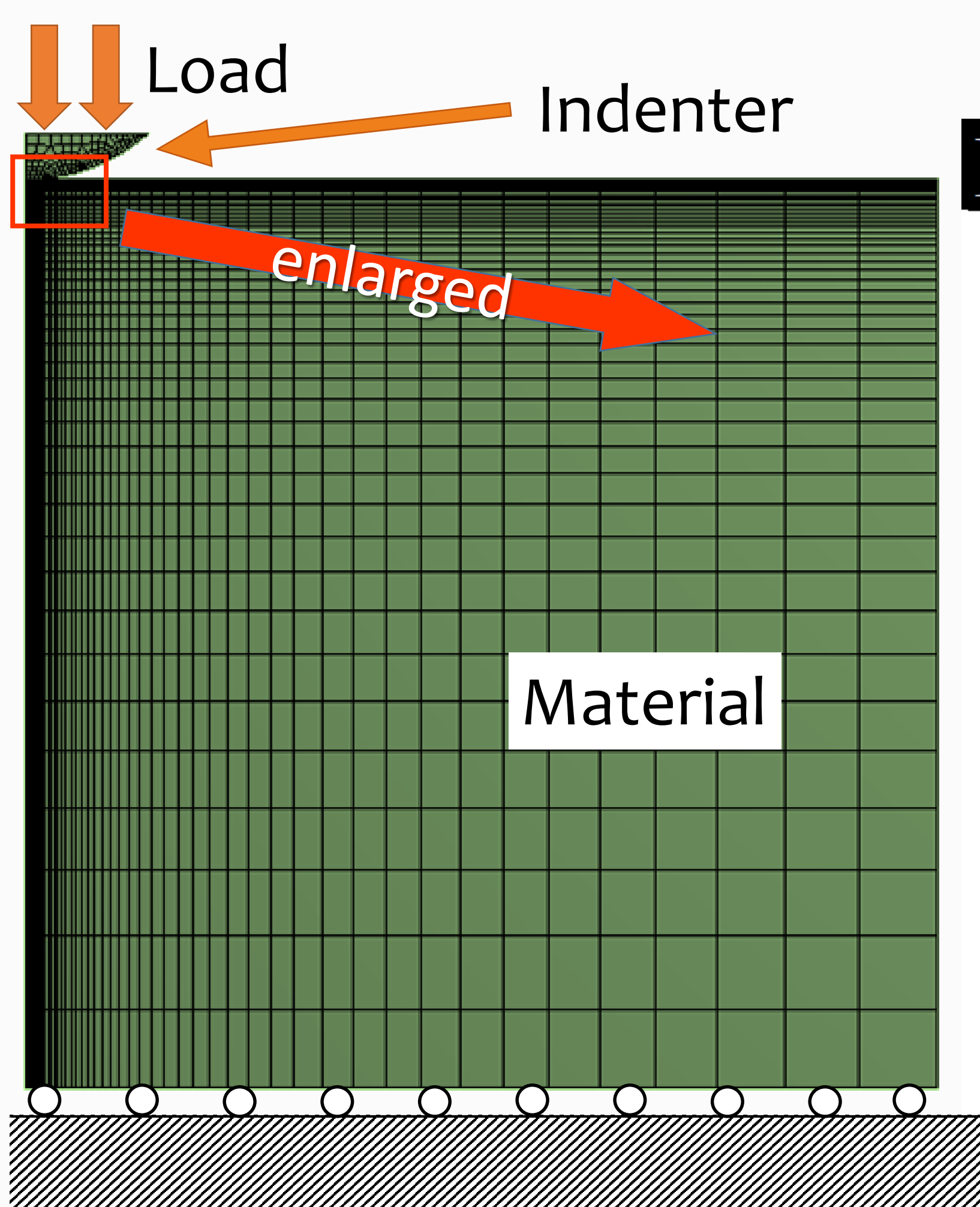
Use of SE materials:

- Medicine (in glasses, stents, dentistry, implants)
- Automotive
- Aerospace
- Sensors and actuators
- Civil structures
- Robotics



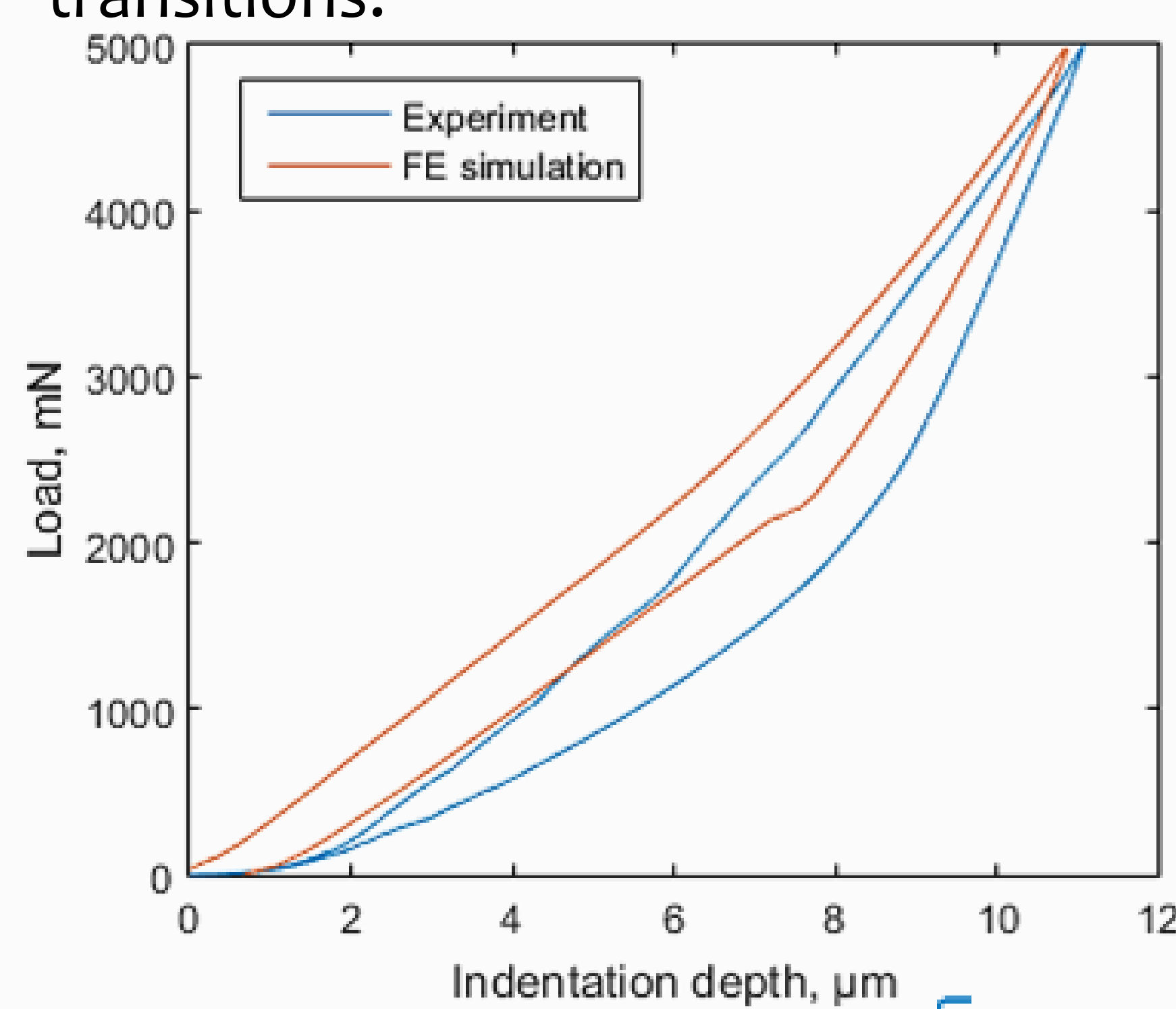
Finite element model and boundary conditions

Areas of different phases at maximum load (enlarged view)



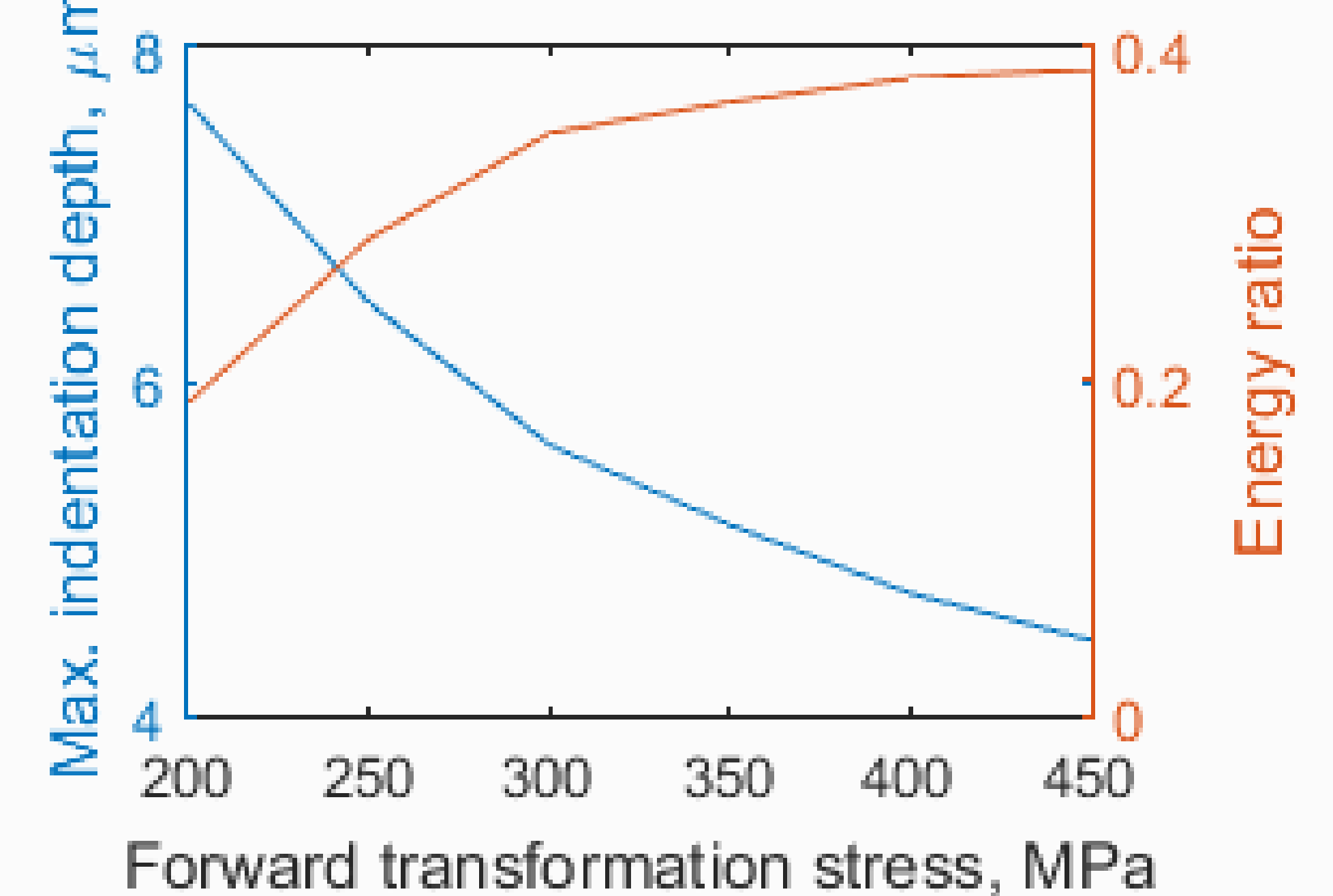
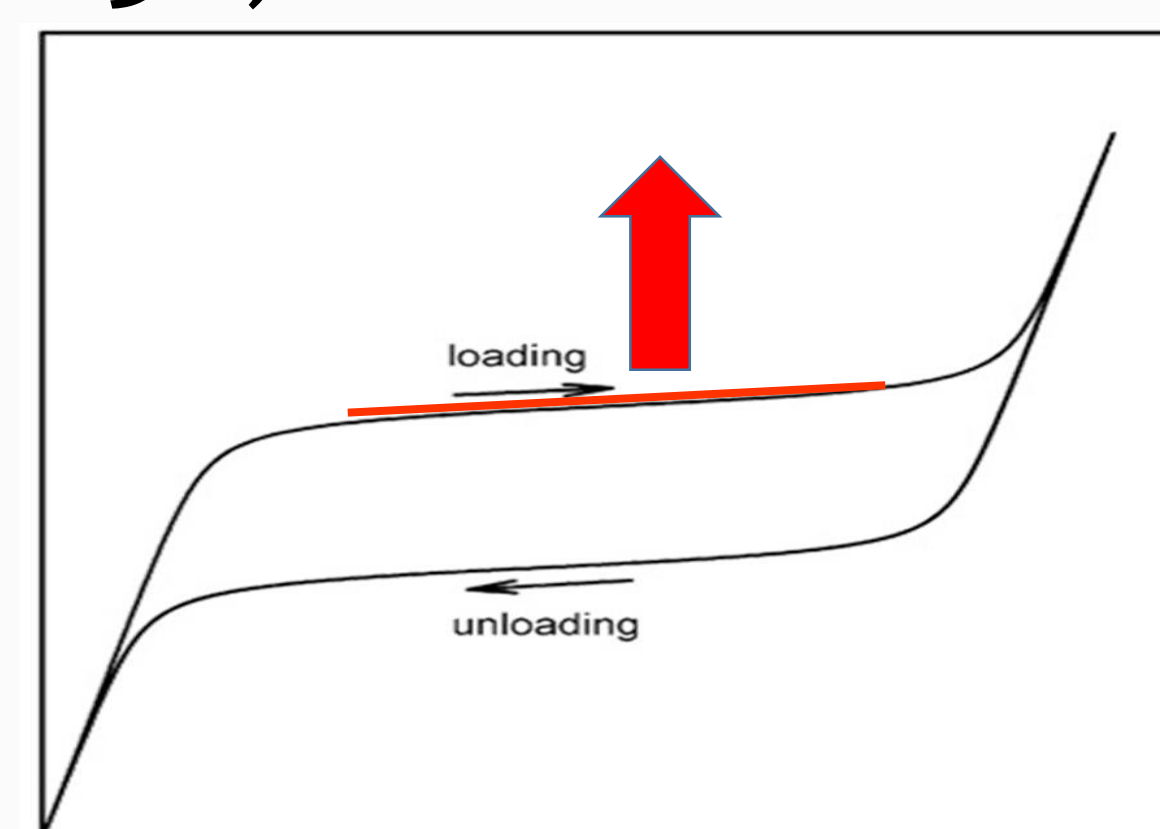
Results

Mechanical properties varied for purpose of understanding the impact they have on results of indentation (force-displacement diagram). Below to the left is quantities what have been varied and to the right is some quantities of simulation results. It includes maximum indentation depth, ration of recovered to thermally dissipated energy. Difference between transformation stress start and finish taken 10 MPa everywhere for both forward and reverse phase transitions.

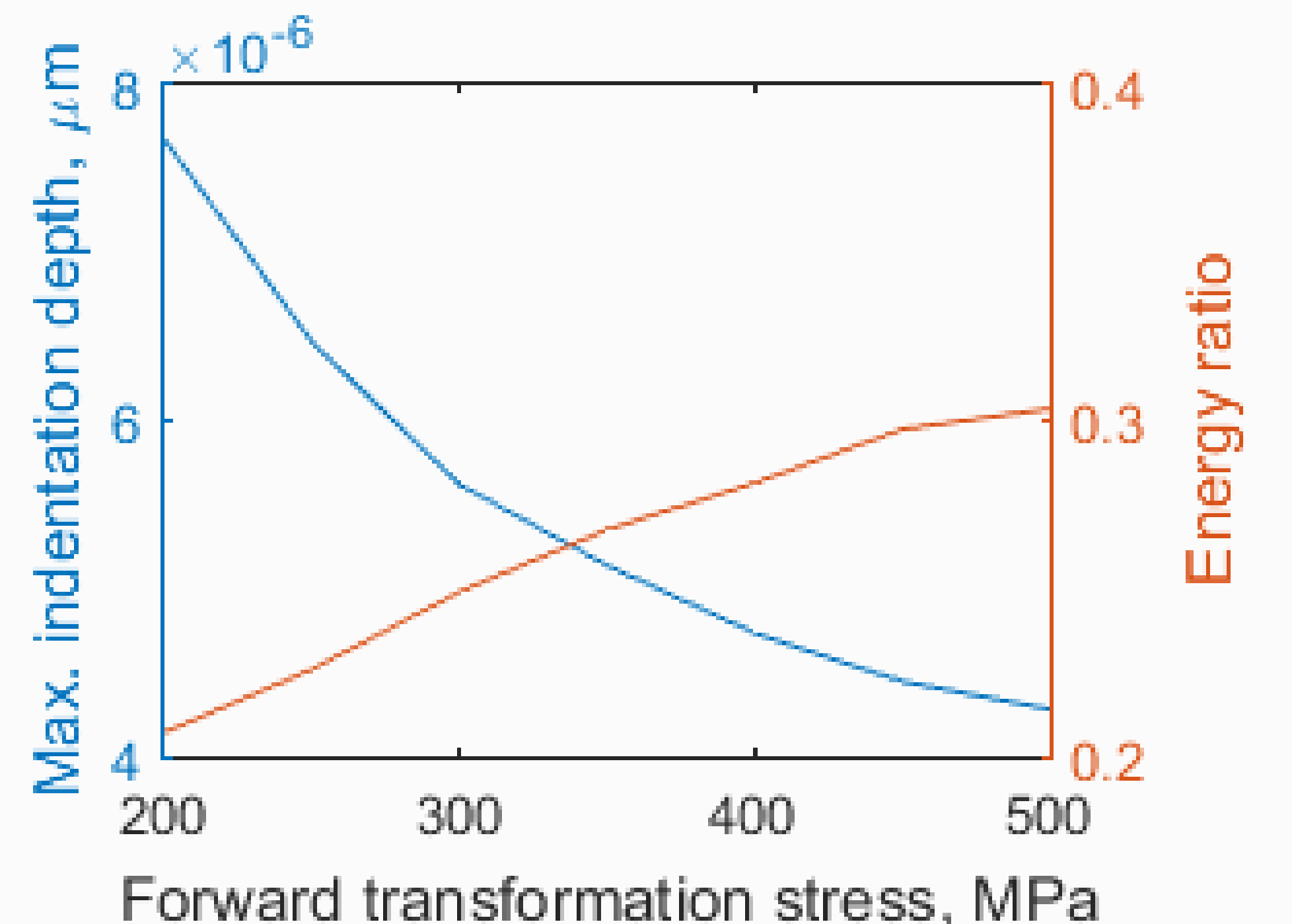
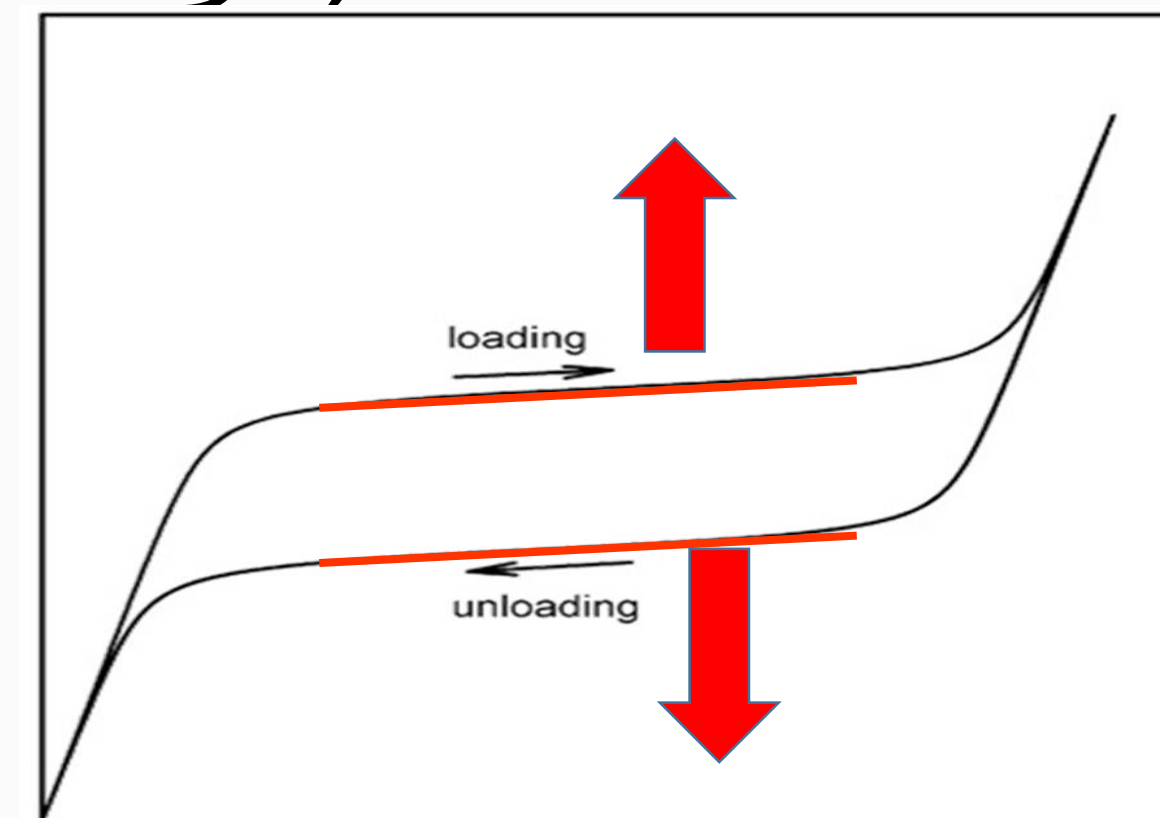


Comparison between FE simulations and indentation experiment for 55.1 Ni 44.9 Ti

$\sigma_f = 200, 250 \dots 500 \text{ MPa}$
 $\sigma_r = 150 \text{ MPa}$, constant
 $\epsilon = 5\%$, constant



$\sigma_f = 350 \dots 500 \text{ MPa}$
 $\sigma_r = 300 \dots 150 \text{ MPa}$
 $\epsilon = 5\%$, constant

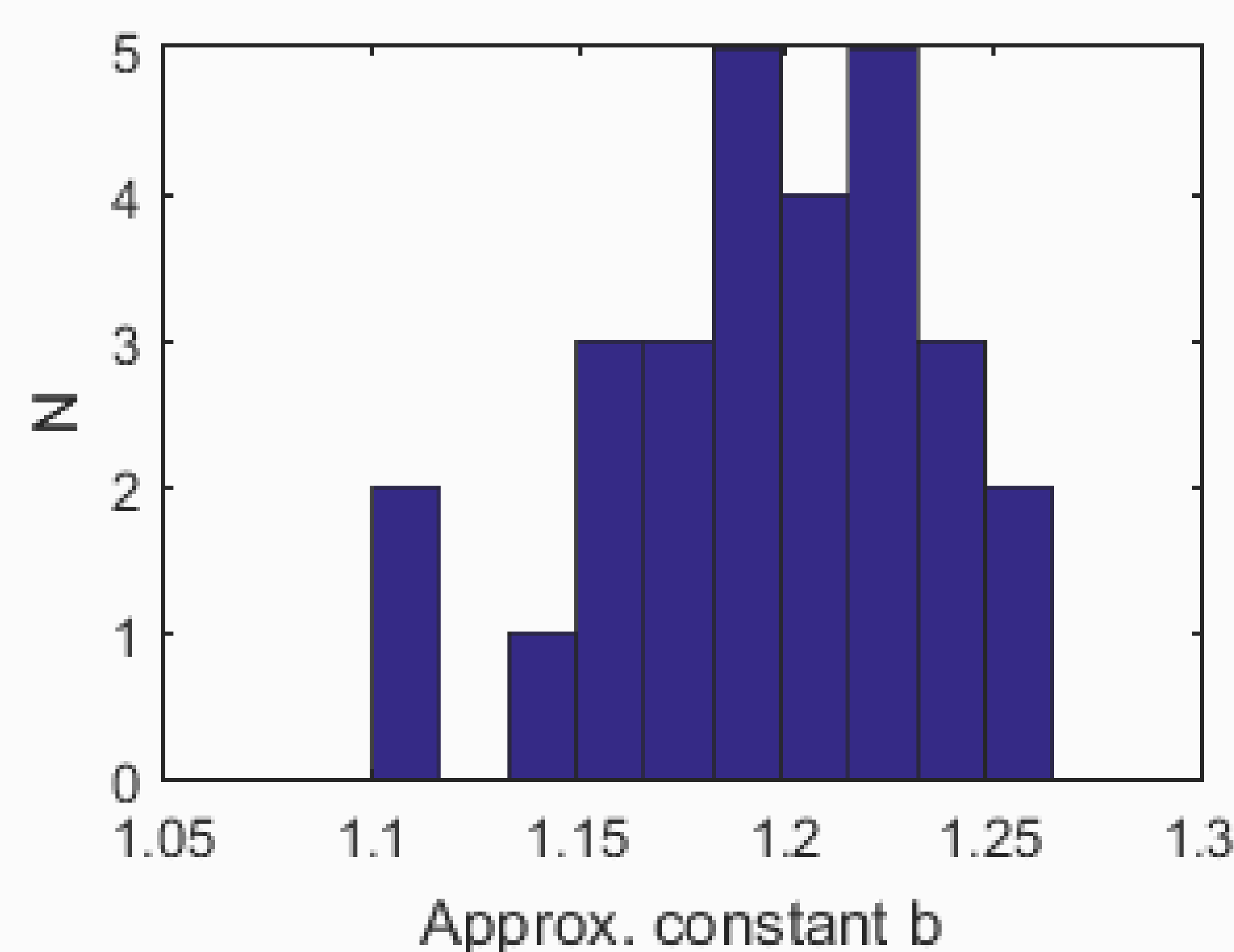


Conclusion

Several series of simulations were conducted with different elastic modulus of austenite and martensitic phases, stresses of phase transition in both directions. It is possible to create a method for determining mechanical characteristics of superelastic alloys using results of various materials' simulations.

Relations between material properties and maximum indentation depth, ration of recovered to thermally dissipated energy and several more is found. Also, discovered that Kick's law (method of approximation of loading curve with square function) is not valid for SE materials.

Authors also want to thank Nikolay Morozov and Sergey Chekanov for help in preparation of specimens for indentation.



$$P = Ch^2$$

$$P = Ch^b$$

$$b \approx 1.22$$