

Stress analysis in a patchy-particle based hydrogel simulation

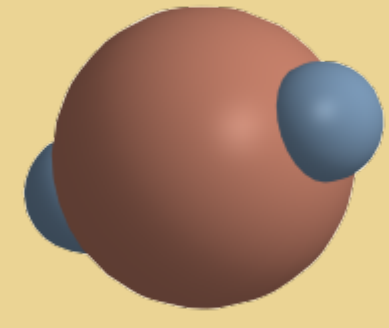
Francisco Javier Vazquez-Tavares¹, Felipe Benavides¹, Caludia Ferreiro-Cordova², Antonio Ortiz-Ambriz¹

¹Tecnológico de Monterrey, Escuela de Ingeniería y Ciencias, Ave. Eugenio Garza Sada 2501, Monterrey, 64849, Mexico
²Tecnológico de Monterrey, Escuela de Ingeniería y Ciencias, Epigmenio Gonzalez 500, Santiago de Queretaro, 76130, Mexico

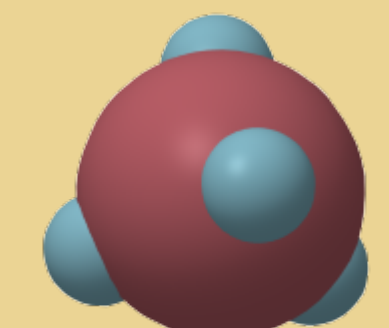
Description of the model

A polymer network is approximated using two types of patchy particles. One with two patches, refer as monomer and a second one with 4 patches refer as cross linker. The patches are spheres of 0.2σ and are symmetrically positioned around a central particle with radius of 0.5σ . The position of the patches is fixed.

Monomer



Cross Linker

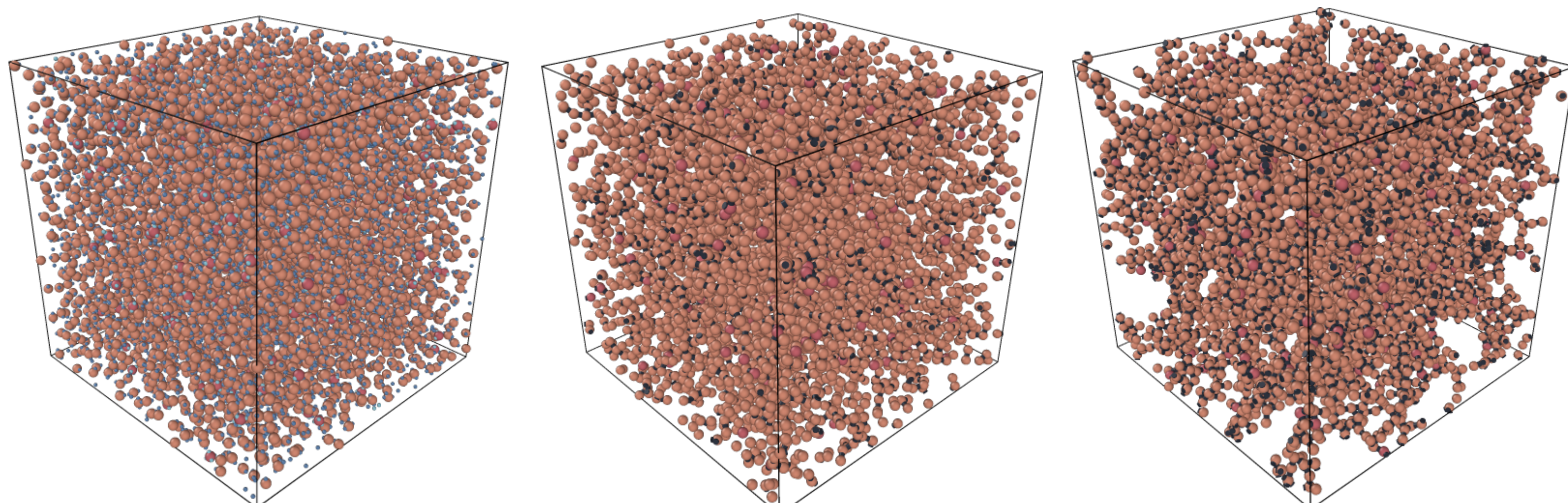


Simulation protocols

A set of two simulations in LAMMPS are performed to approximate the polymer structures and apply a shear deformation. The simulation to approximate the polymer structures consists of a heating-up process and an isothermal process. Then, a shear deformation is applied in the xy plane with different shear rates until the desired deformation is reached with constant relaxation periods between deformations.

Heat up

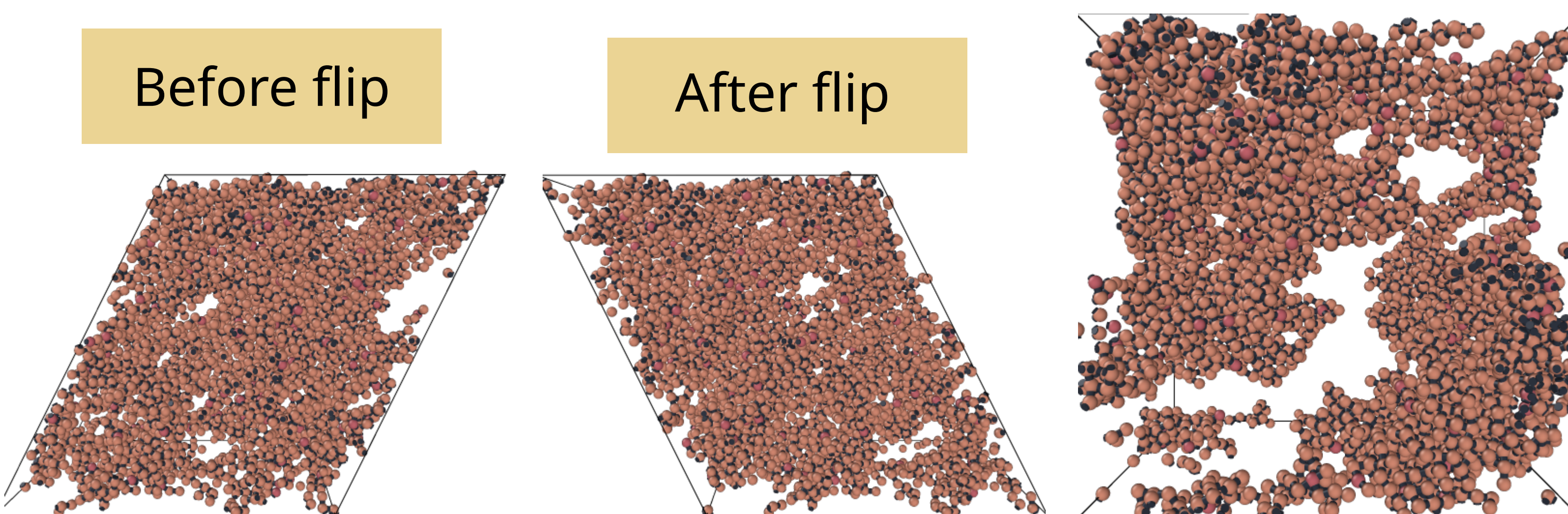
Isothermal



Shear deformation and relaxation intervals

Before flip

After flip



Conclusion

From the initial exploration of the relation between the yield stress-shear rate relation we found a guide to classify the deformation behaviour through well-known models such as the Herschel-Bulkley model. On the other hand, from the set of deformation cycles with relaxation intervals between them we observe a stationary value of stress after the relaxation intervals.

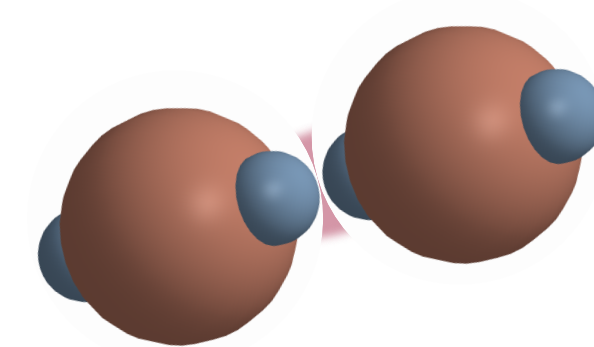
In further explorations we want to find relations of the polymeric structure through different cross-linker concentrations at different shear rates to see how the yield-stress changes and compared them with the results from cycles of deformations with relaxation intervals.



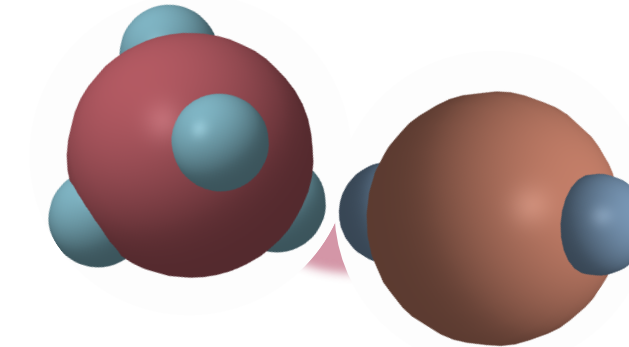
Interaction between patches

The central particles interact between them via WCA potential, meanwhile the patches interact with an attractive potential and a three-body potential. The central particles and the patches do not interact with each other.

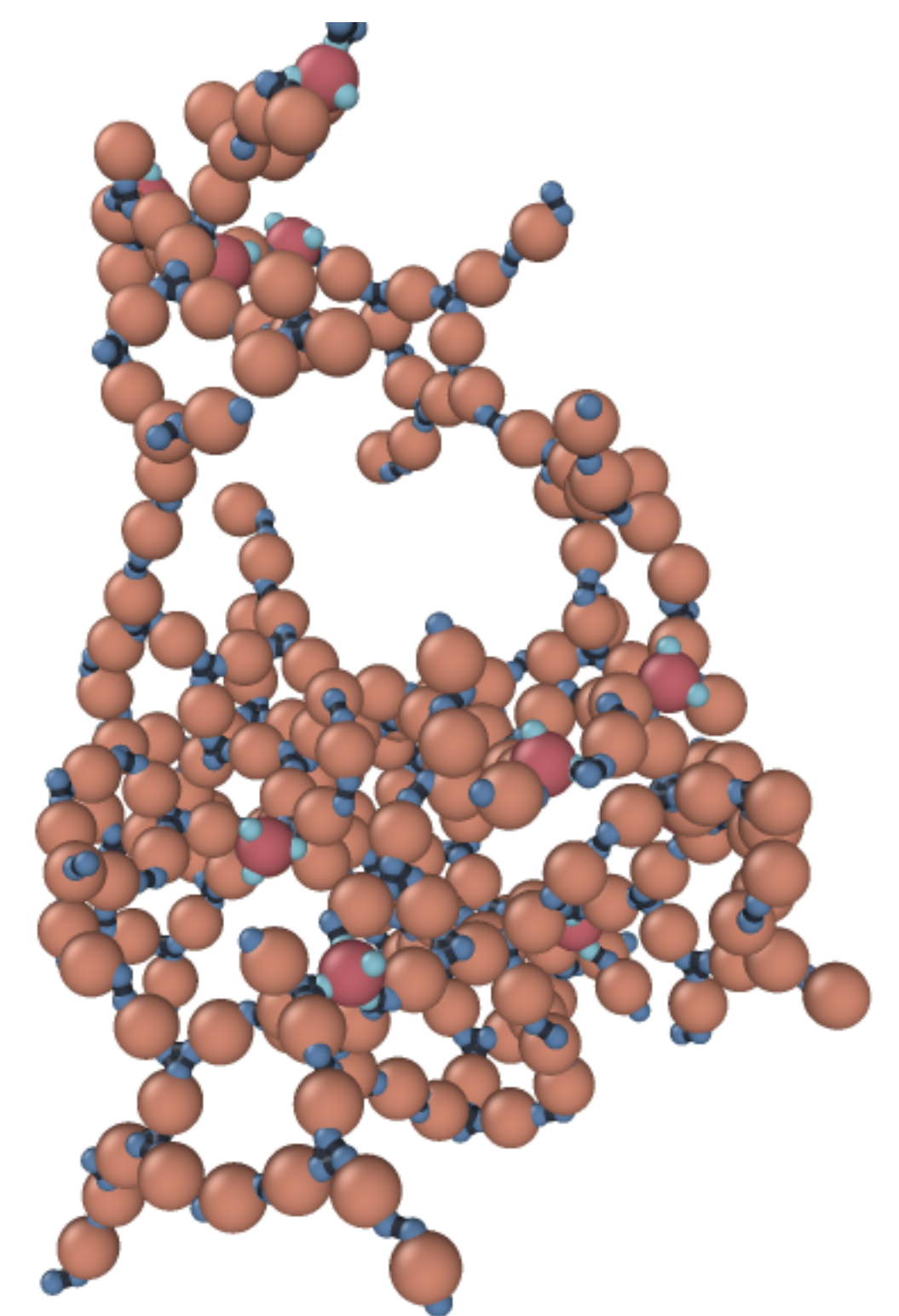
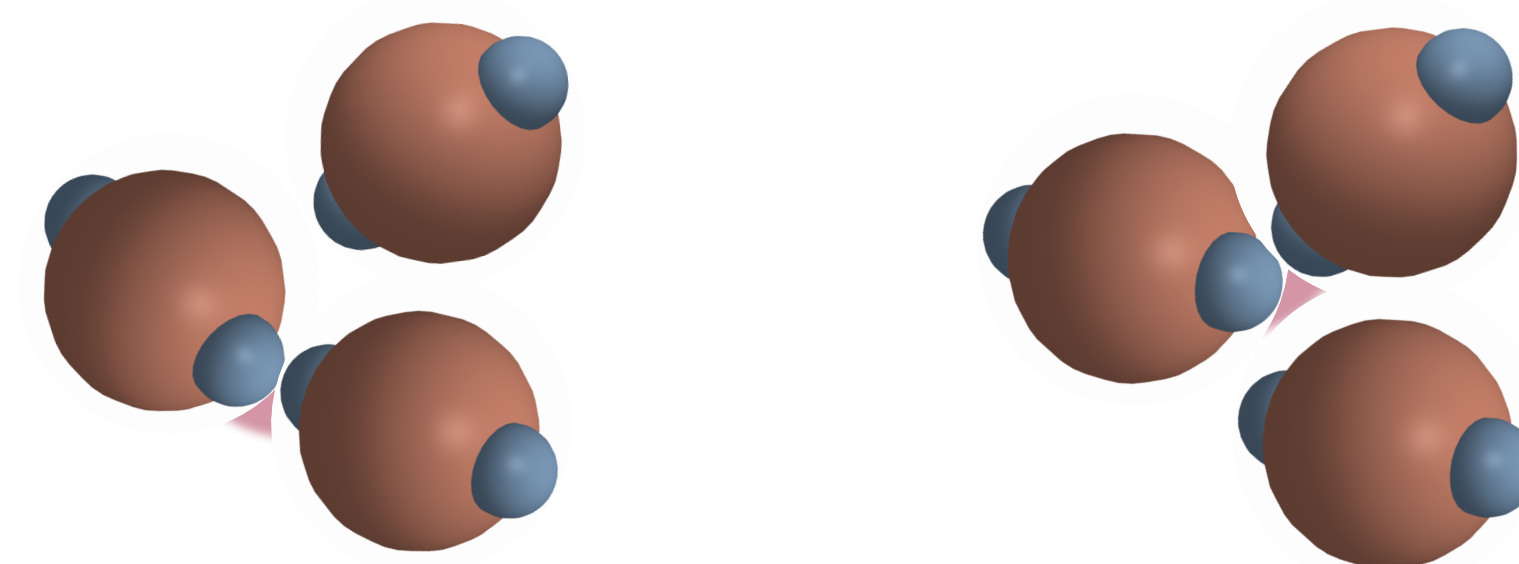
Patch B - Patch B



Patch A - Patch B

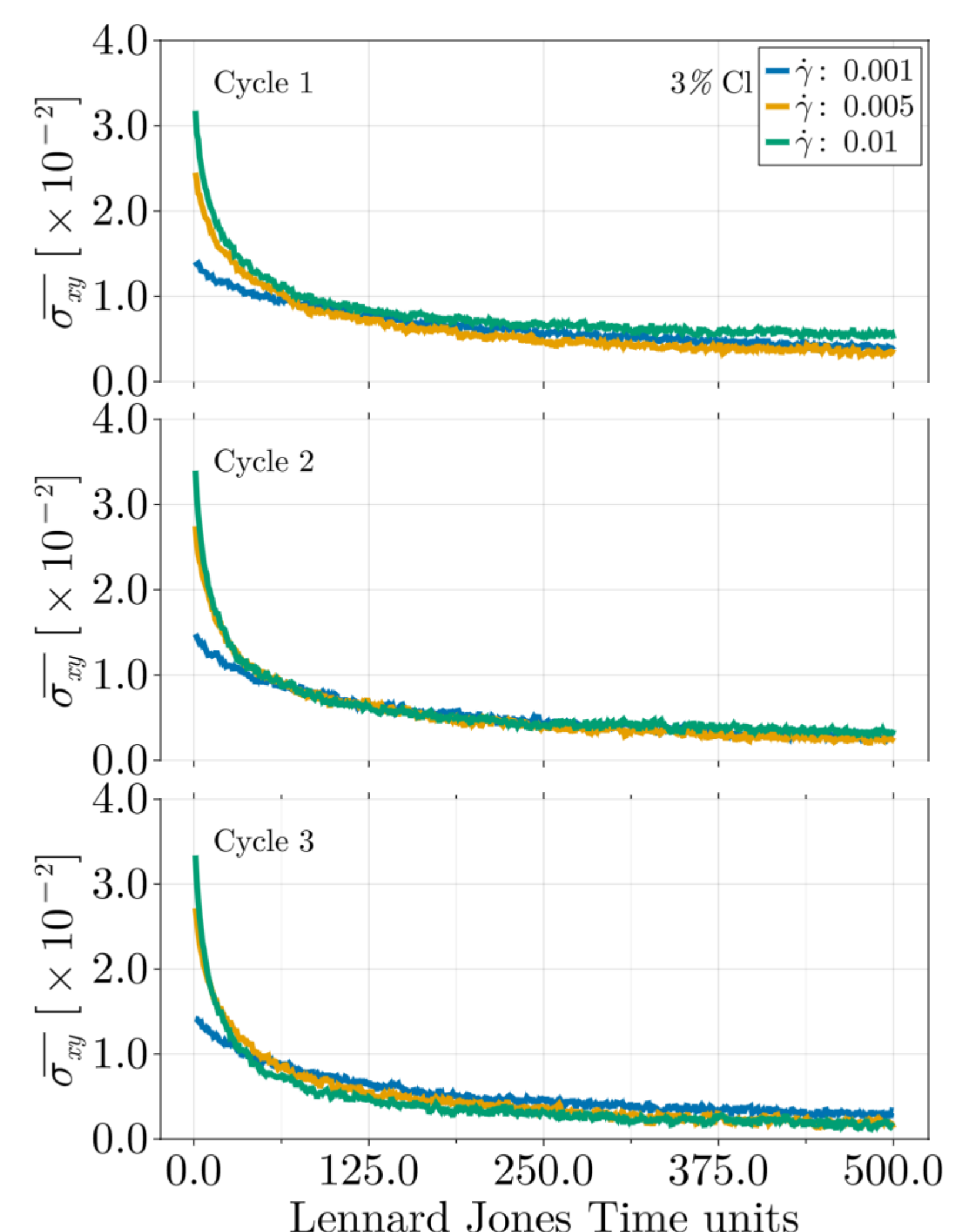
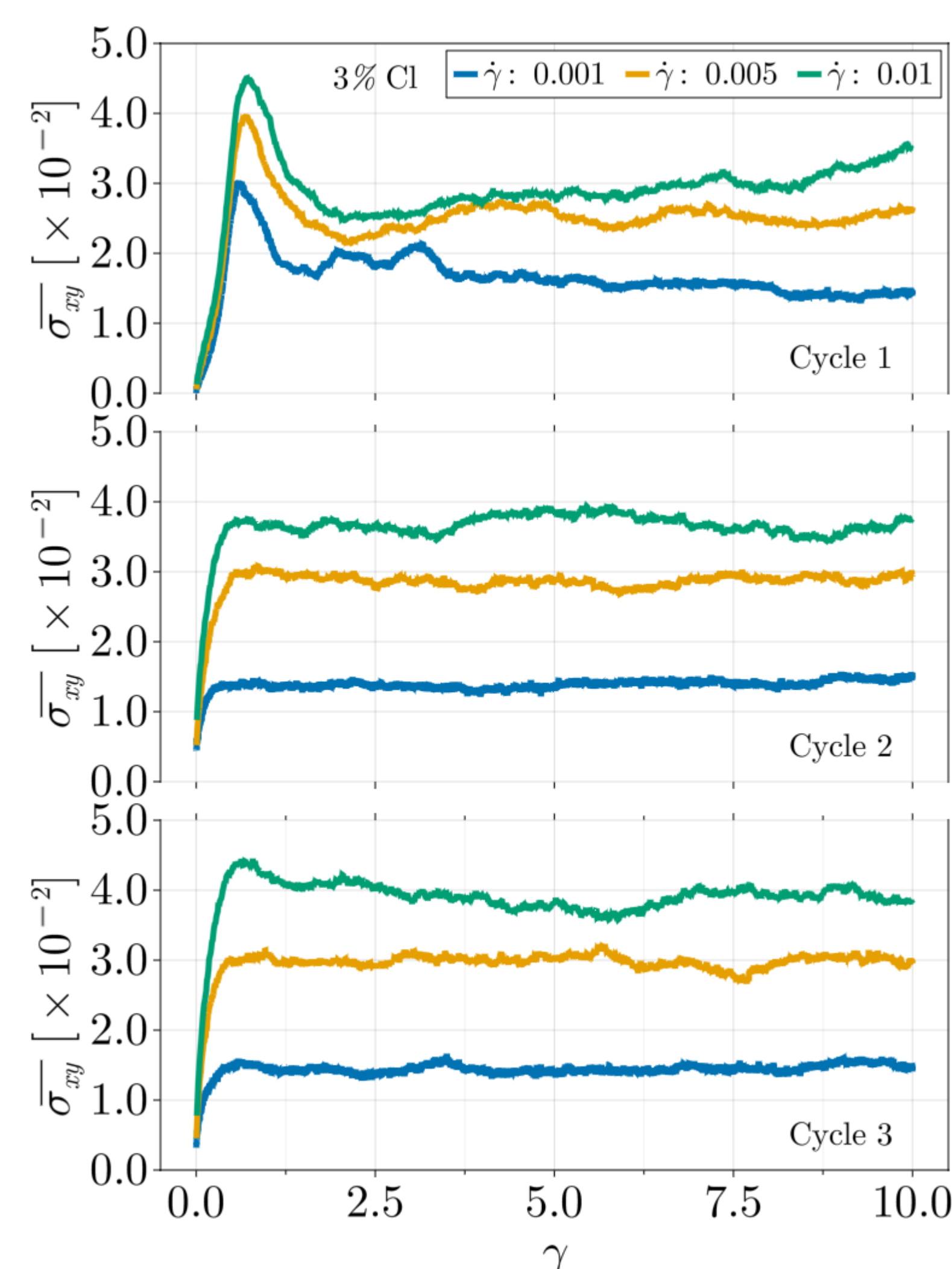
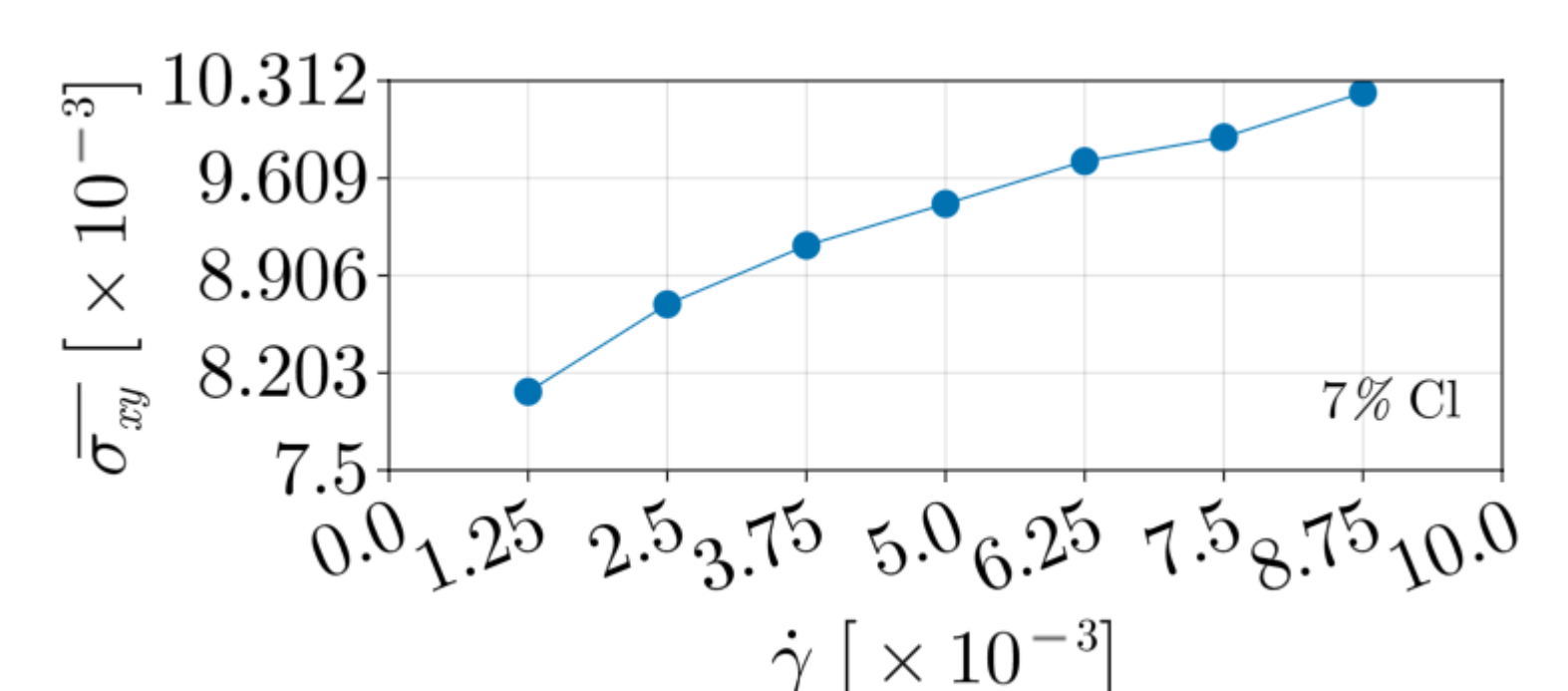
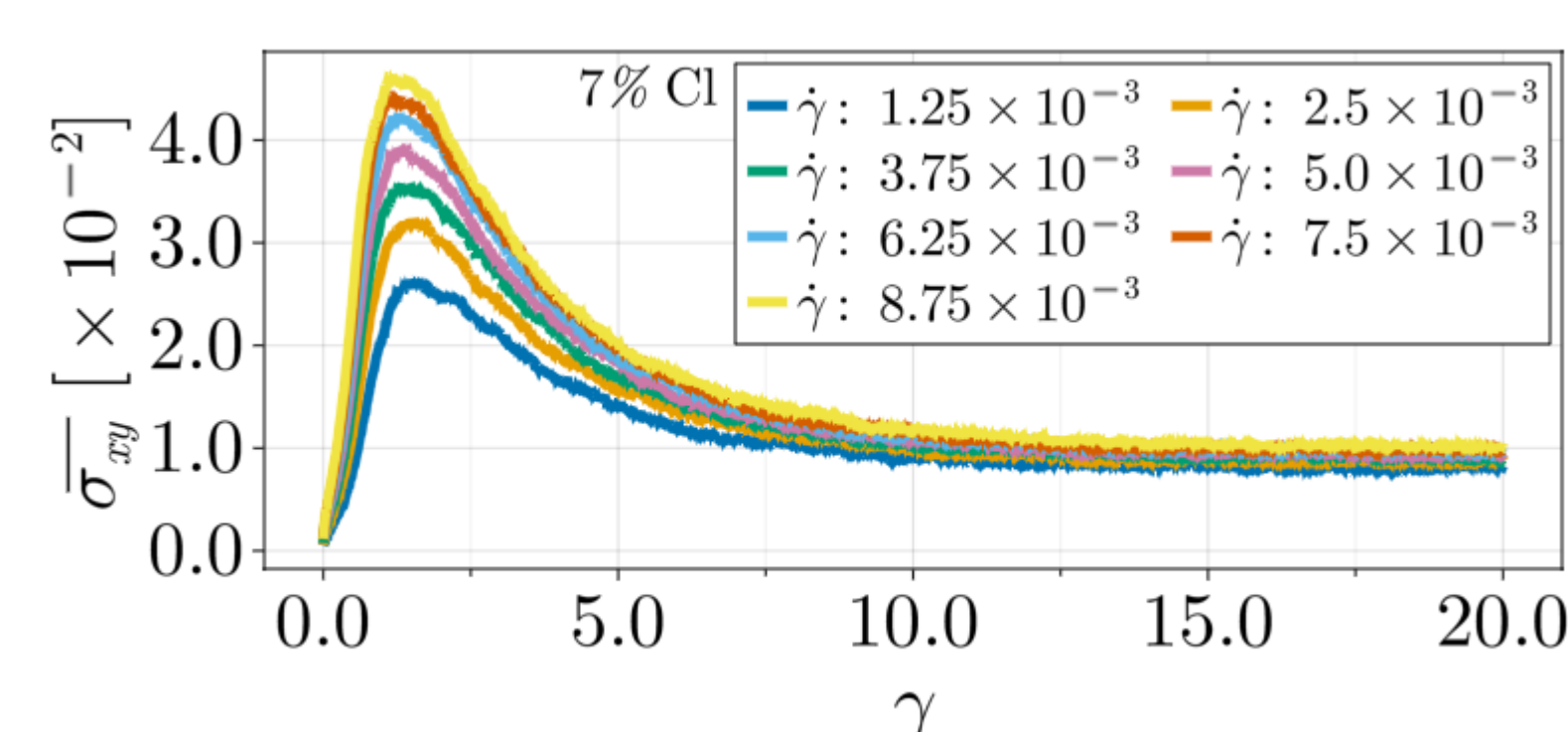


Swap Mechanism



Results

We report the temporal average of the xy component of the virial stress tensor at different shear rates and cross link concentration with respect to the deformation and a yield stress curve of the stress from the stationary state of the system of the deformation process. Finally, it is added the stress during the relaxation period between deformations.



References

Nicoletta Gnan, Lorenzo Rovigatti, Maxime Bergman, and Emanuela Zaccarelli Macromolecules 2017 50 (21), 8777-8786 DOI: 10.1021/acs.macromol.7b01600. Valerio Sorichetti, Andrea Ninarello, José Ruiz-Franco, Virginie Hugouvioux, Emanuela Zaccarelli, Cristian Micheletti, Walter Kob, Lorenzo Rovigatti; Structure and elasticity of model disordered, polydisperse, and defect-free polymer networks. J. Chem. Phys. 21 February 2023; 158 (7): 074905. <https://doi.org/10.1063/5.0134271>