Contact Methods

Ahmed Elgailani - June, 17, 2020

Last update:

July 6, 2020

1 Overview (Storyteller style!)

In this report, I want to document the development of the way we handled the contact problem in our model. The first code handed to me by Craig was using node-to-node (NTN) method to prevent interpenetration between the particles. It is a simple pair-wise repultion between surface nodes. However, the measured modulus using this method showed a super-flory behavior which raised our skepticism about the validity of the NTN method, namely the effect of the no man's land the NTN method artificially creates in the system which we suspected might result in increased rigidity of the system as a whole. To evade the no man's land issue, we decided to use a different and more sophisticated method known as node-to-segment (NTS). In this method, we find the point of closest approach from each surface node to any potential "master" surface and apply a penalty if an overlap is detected. However, we noticed a kind of "locking" behavior at some facets that, we suspect, increases the modulus by preventing sliding. We then focused our attention back on NTN method. I also tried new variations of the method, like ghost-node-to-node method in with I introduce more fixed repulsion points that are not part of the mesh degrees of freedom (ghost nodes) on each segment connecting two main sruface nodes. This later method has the advantage of enabling us to cut the no man's land by a significant factor for the same maximum safe pressure the system can sustain without subjecting surface nodes to a significant tangential traction. This report is to highlight the anaysis we did to arrive at the following temporary conclusions as of tody, Mon, Jun 29, 2020:

- The NTS method has a locking behaviour when used with our linearly discretized surfaces. The extend to which this behaviour is affecting the shear modulus is unkown to us as of now. NTS method also has corners an issue at high ϕ values that remains to be analized.
- NTN method does not have the locking we see in NTS as long as we use σ/a parameter that is suitable for the desired pressure of the systm. Meaning, σ/a at a particular pressure should be high enough to ensure a neglibible tangential components at the facets. But the desire for high σ/a competes with the desire for a smaller no man's land artifact. One way to reslove this issue is to use a modified NTN method, GNTN, which could be the best candidate so far.
- For linear response, Kirkwood contribution is significant and should be included in the calculations of the modulus.
- A finite R_{cut} leads to spikes in the modulus curve when R_{cut}/σ is relatively small (around 2.5 roughly). To avoid that, we added a linear term to the repulsion force (which means is a harmonic term to the contact potential) and it succeded in resolving the issue.

2 NTS method

2.1 Locking problem

Upon the point where we wanted to make measurments of the modulus using the NTS contact and GD, Craig noticed a locking behaviour. Figure 1 shows the velocity field that casused us to reconsider the reliability of the NTS method for the purpose we are seeking. Notice that facets like the ones between particles 2-5 or 5-8 are showing a continuity in the velocity accross the facets. This behaviour is problematic because we it could increased the modulus by preventing the material near the facets from relaxing the shear stress by slipping as one would expect to happen. The cause of this locking we beleive is an inherent flaw in the NTS contact for linearly discritized surfaces. Notice the interdigitation between similar size meshes in figure 2.

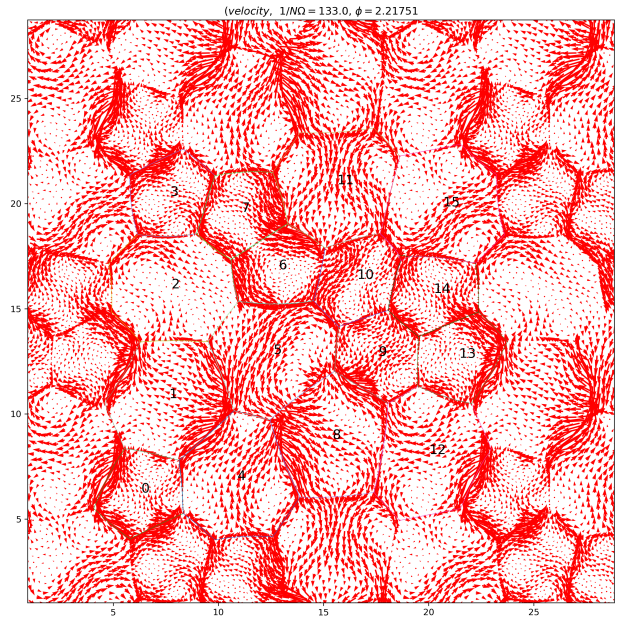

Figure 1: Non-affine velocity during shearing with NTS contact. Notice that facets like the ones between particles 2-5 or 5-8 are showing a continuity in the velocity accross the facets.

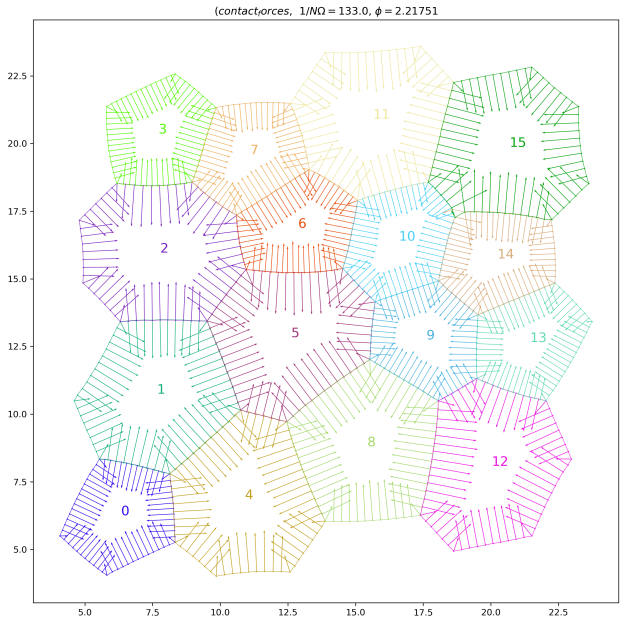

Figure 2: Contact forces during shearing with NTS contact. Notice the interdigitation between similar size meshes.

3 NTN method description

3.1 NTN Convergence analysis

Figure 3 shows the modulus of a three particle equilateral system with different parameters and mesh sizes. We notice that for the same mesh, namely cir64, the coarsest mesh, the curves with dt=0.05 and with dt=0.02 are almost exactly on top of each other. However, the initial shock relaxes faster when we use slower rate ($\dot{\gamma}$). Compare the curve with $\dot{\gamma} = 1E-6$, the purple one, with $\dot{\gamma} = 1E-5$, the blue and red ones, and $\dot{\gamma} = 1E-4$, the brown one. Notice that the higher $\dot{\gamma}$ the slower the relaxation of the shock and lower the converged value of the modulus. This rate dependence explains why the finer meshes, the orange and the green curves, are slower to converge. The conclusion is the finer the mesh, the lower $\dot{\gamma}$ reguired for a quick convergence. In other words, if we use a slow $\dot{\gamma}$ with finer meshes we would see a convergence of all of the three meshes to the same value with insignificant difference in μ.

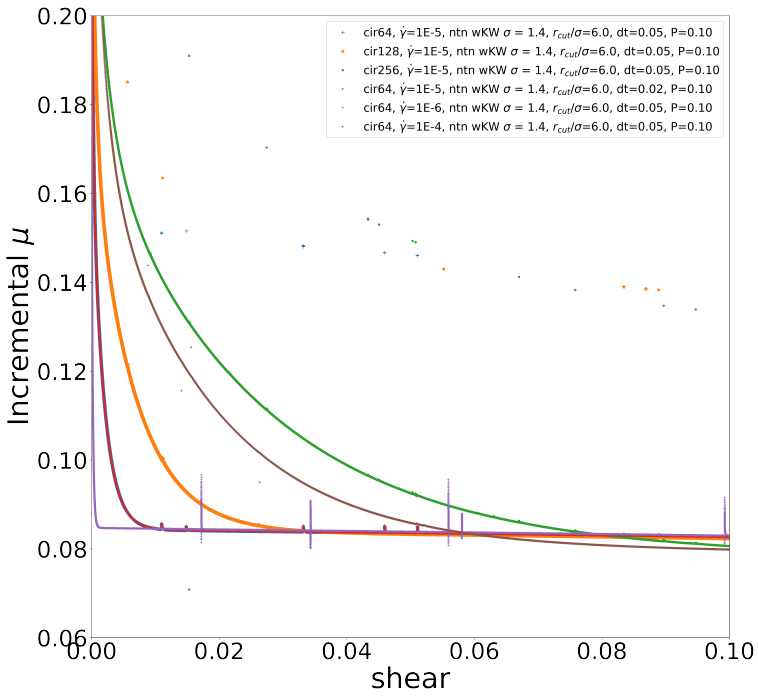

Figure 3: μ vs shear strain for a three particle equilateral system with NTN contact for different repulsion parameters and meshes sizes.

4 GNTN method description

5 Convergence analysis

5.1 Effect of Kirkwood stress contirution

Figure 5 shows the effect of including Kirkwood contribution in stress calculation on the measured μ. It is clear that it is significant, at least for the current system. notice that ignoring Kirkwood stress lowers the modulus which is reasonable because this will reduce the calculated difference in shear stress for the same strain, as the deformation energy is obsrbed both by the material and buy the contact no man's land

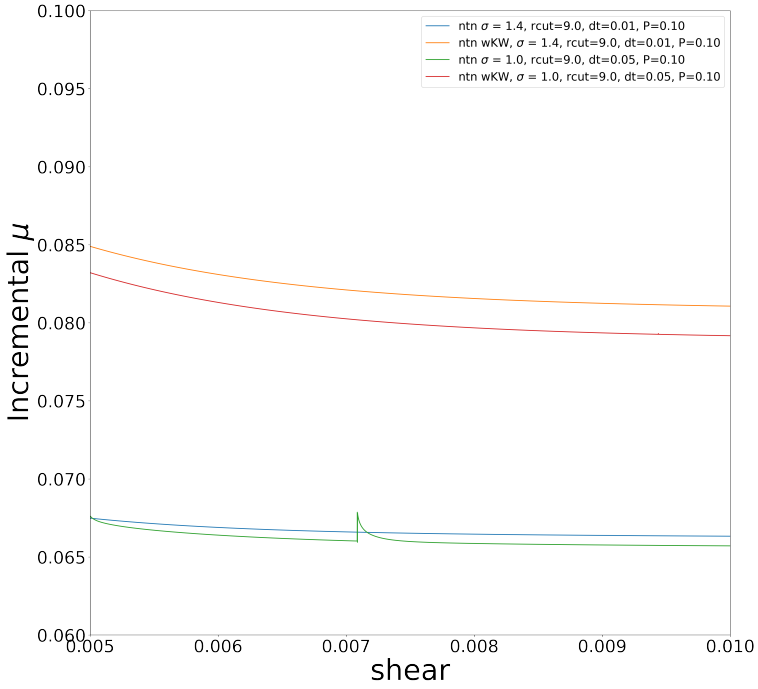

Figure 4: μ between consecative time steps as a function of shear strain for three particels in a traingle for two different values of σ for two cases, with and without including Kirkwood contribution in stress calculations.

5.2 Effect of R_{cut}

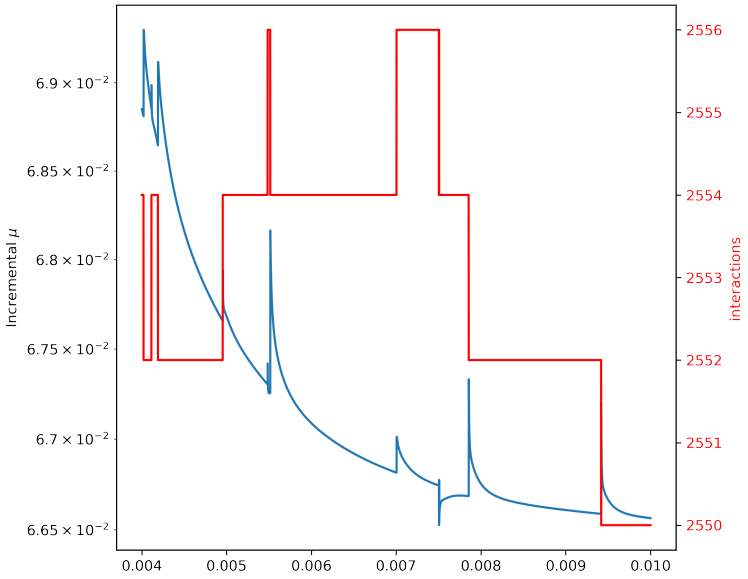

Figure 5: μ and total number of pair interactions as a function of shear strain for three particels in a traingle. This figure verifies that the spikse we noticed in the modulus curves are the result of nodes coming in and out of stencils. This was before we added the linear term that reduces the shock and and we take R_{cut} at the point where the force is zero after the addition of the linear term