Optimization of Fracture Propagation by Bifurcate Tri-Clawing

Author: Yixiao Zhang
Associate Author: Nima Rahbar
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Worcester Polytechnic Institute

Abstract

For optimizing fracture propagation underlying stretching out effect, take advantage of triangle lattice structure associated with truss and beam bonds to investigate macroscopic material. Referred to analytical results, failure threshold of bond is assumed by 10 percent of own elasticity. When sprawl the system at two ends with margin boundary condition, the simulation results are less than 7% error to analytical solution, so triangle lattice is a remarkable and accurate model exploring cracks evolution. But if investigating fracture propagation started from middle part, its boundary conditions should be locked close to middle part alike sleeve harnessing on a stiff component. To fortify structure causing extra loading capacity, this paper designs a bifurcate tri-clawing motif giving those bonds 2 to 10 times elasticity escalation in each hexagonal cell. In this regard, although the global material obtains adequate strength reinforcement through optimization, it nevertheless loses ductility as expense of stiffness, that is decrease of toughness.

1. Truss system

Microscopic structure makes up of equilateral triangle apiece connected by truss components to simulate fracture propagation of macroscopic material sprawled at two ends. Due to symmetry, all cases in this paper are considered an 8 by 16 by 2 stereo structure as half of object. Inspected fracture propagation started from middle part, it’s pinned along the entire top side and middle point at bottom and set roller along rest of edges but keep a patch of space free at either lateral side close to bottom, in Fig 1. When outward stretching displacement acted on hinged edge increase evenly, in Fig 3, one can observe that unanimous truss model performs steady elongated deformation until reaching collapse threshold in an instant, in Model 3 and 4 in Fig 3.

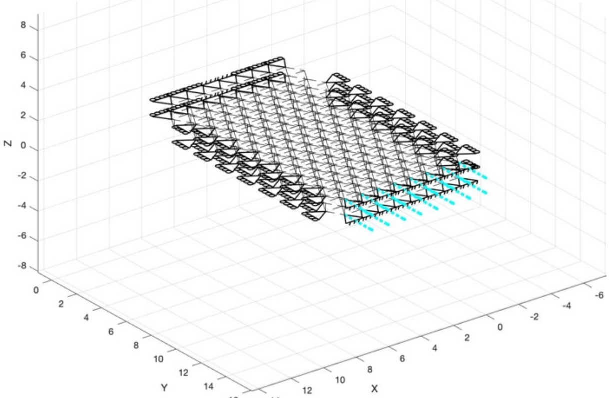

Fig 1

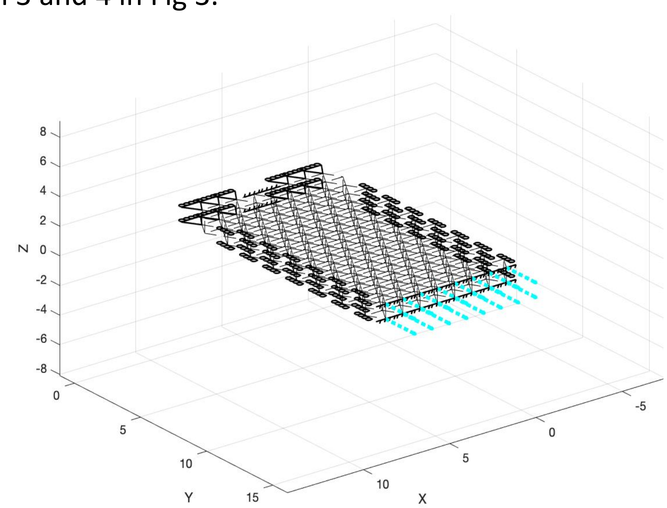

Fig 2

Because truss, with 3 degree of freedom, do not possess bending capacity, bottom components are crumbled simultaneously to cause system collapse as elongation approaching to 1.7 units length.

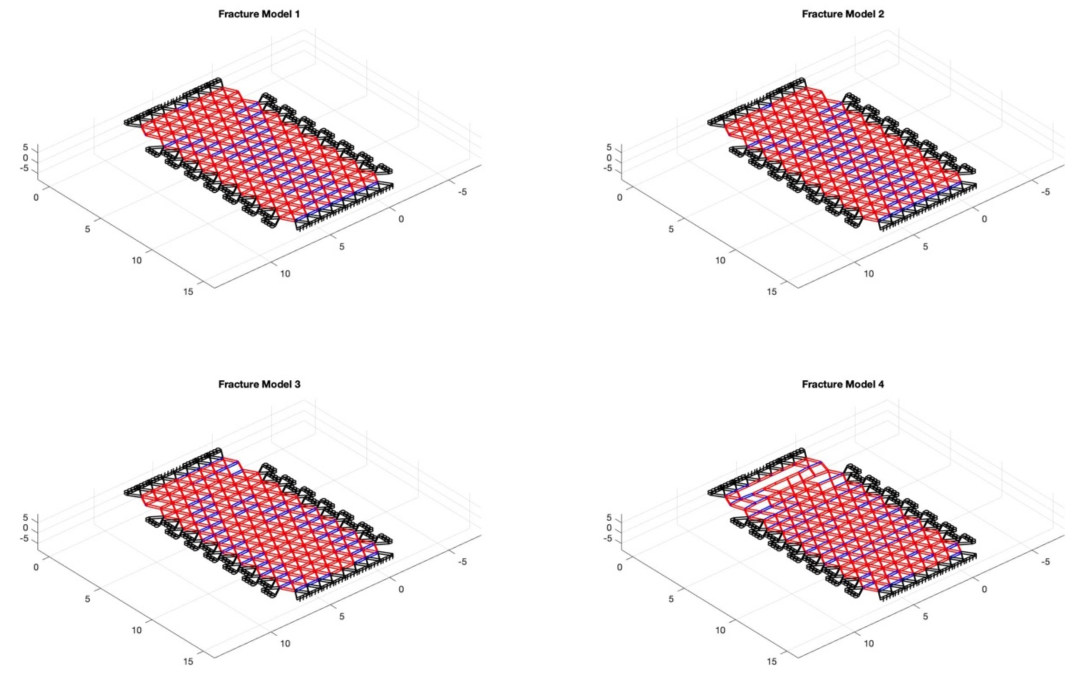

Fig 3

2. Beam system

On contrast to ingredient of truss system, beam model is inevitably fixed at each node with 6 degree of freedom so that global system is of superior toughness than truss framework. Sustain identical boundary conditions with forementioned example. Once outward elongation of displacement causes local components reaching maximum load capacity, one can observe apparently, Model 2 to 3 in Fig 4, that cracks are evolved from middle part gradually, beginning break from margin to middle part until only solely sticked by two components before collapse.

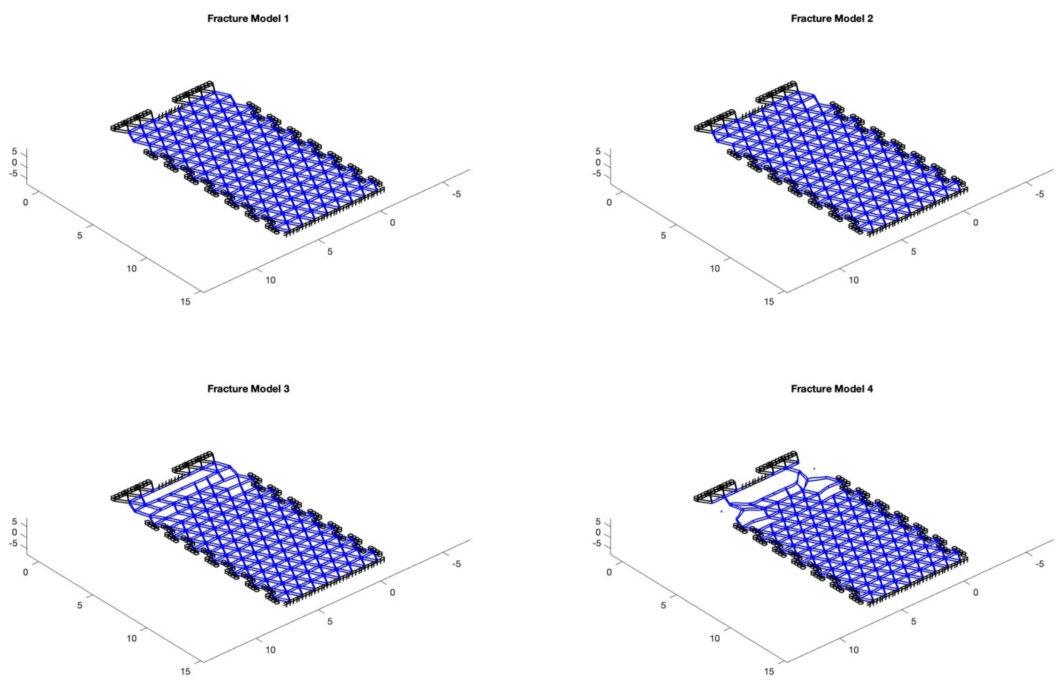

Fig 4

3. Tri-clawing reinforcement

Given that triangle lattice is of remarkable stability and accurate simulation results, it is worth to be used to investigate material fracture propagation and corresponding structure enhancement. Tri-clawing motif reinforcement, in Fig 5, was defined by that the bifurcate components connected at one node in each hexagonal unit are specifically fortified through escalating its own elasticity. Scaling up from 1 to 10 respectively, solid line, in Fig 5 and 6, represented by intensive components would award an optimal strength but with inferior toughness as result of ductility reducing.

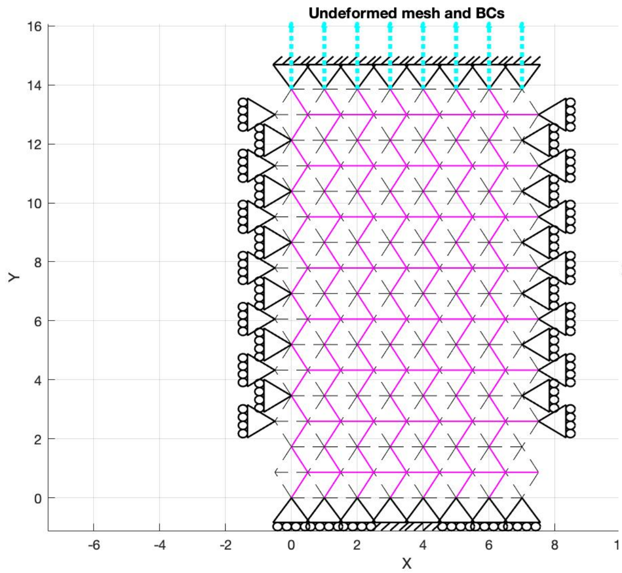

Fig 5

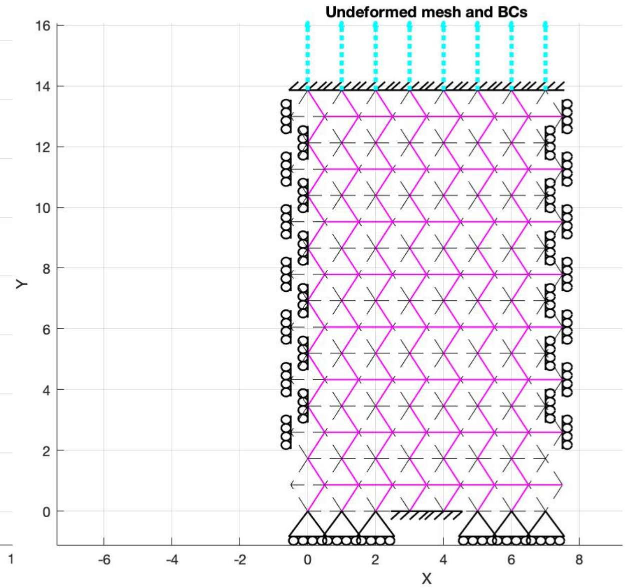

Fig 6

4. Simulation analysis

Directly assigning various value in simulation code, one can acquire relationship of force and elongation as following diagram. In truss system, the bottom graph referred to unanimous material, in Fig 7, is developed smoothly but breakdown all of the sudden at 1.7 units length. But with amplification ratio by 1 to 5, though it still obtains extra strength, the global system starts to lose toughness as expense of stiffness improvement. Additionally, strength of global truss object begins decrease within the scope of grade from 6, in Fig 10 dash line.

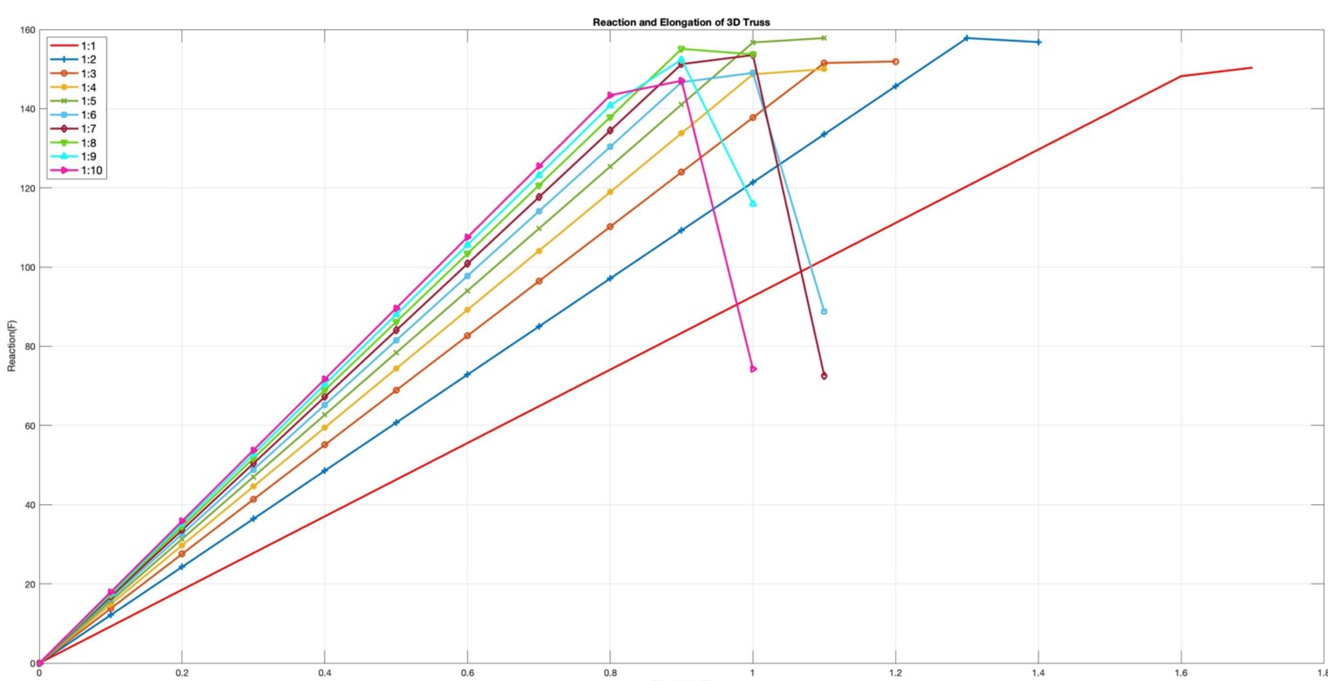

Fig 7

Contrast to foregoing example, beam system has obviously steady improvement of strength reinforcement and relatively superior toughness as result of bending capacity. Therefore, strength of beam system is exactly improved by 20% by bifurcate tri-clawing motif at level 10, in Fig 10.

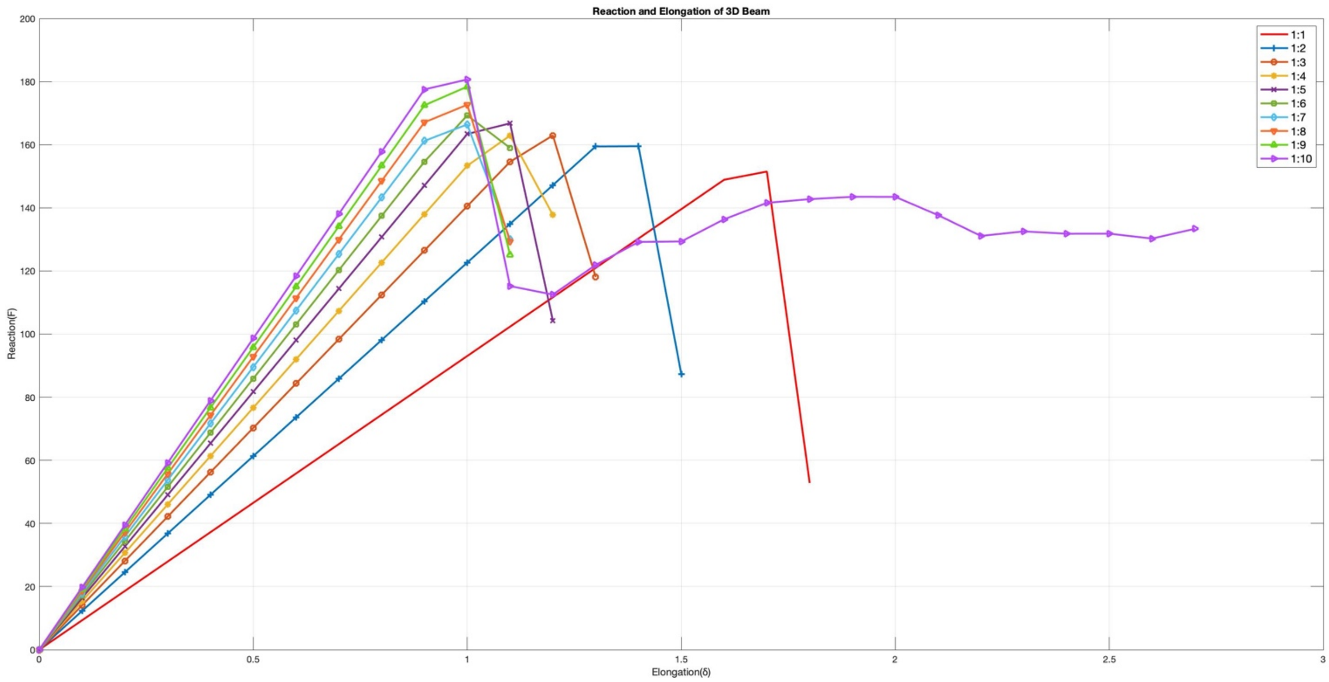

Fig 8

When compare diagram on level 10 in Fig 8, uniform breakdown of local components marches gradually forward to object centroid and even to the top at terminal collapse, in Fig 9. Because fortified members have been granted adequate stiffness resisting collapse, even majority of un-fortified members demolished. As the result, this extraordinary improvement award structure possessing two phase fracture propagation, inevitably granting the most excellent toughness at same time.

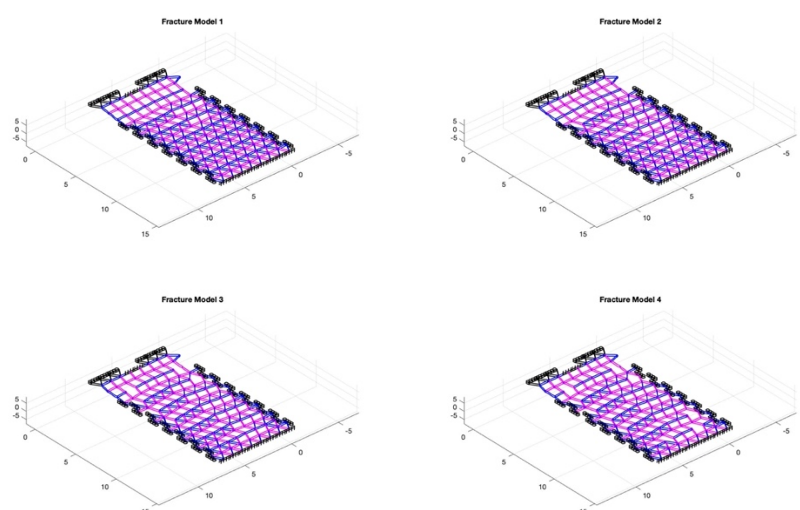

Fig 9

5. Optimization of fracture prevention.

For better understanding advance in bifurcate tri-clawing reinforcement, one should investigate optimal fracture protection scheme associated with strength and toughness as well. In Fig 10, combined with ratio 1:2, both systems are of optimai strength and toughness as desired scheme resisting collapse due to fracture. Additionally, beam system underlying bending capacity thus have prominent improvement of strength and toughness at level 10, but truss system, in turn, decrease of that of capacity after level 6.

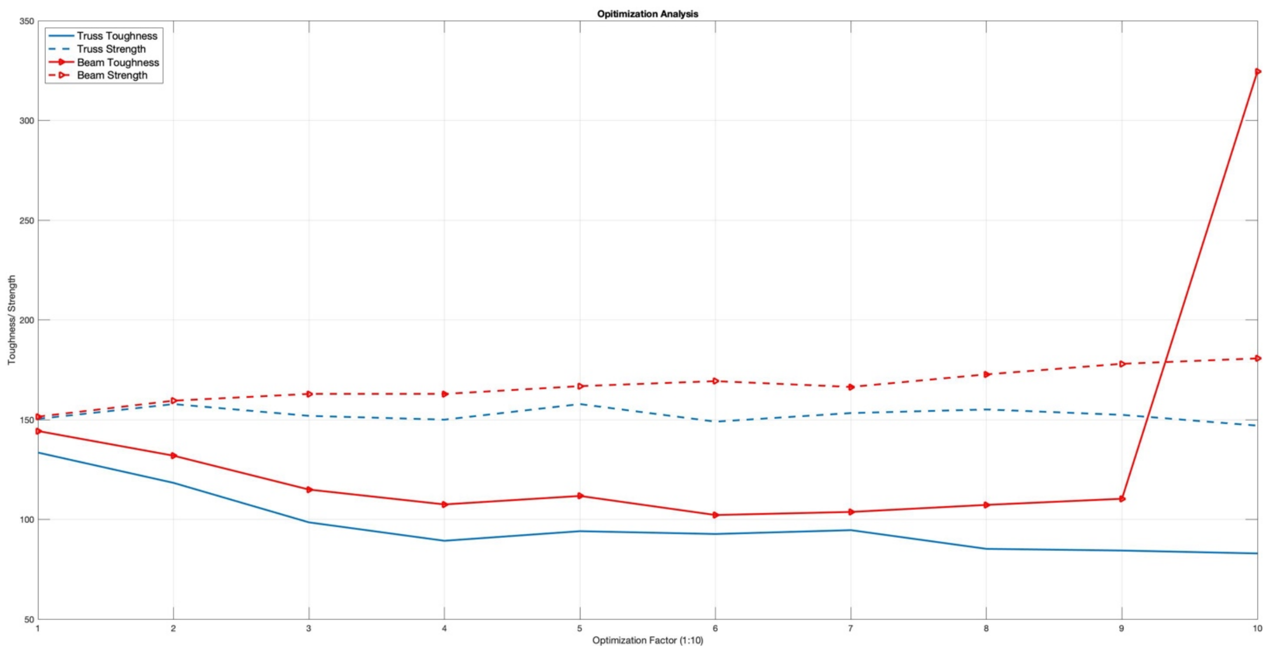

Fig 10

6. Conclusion:

1. Triangle lattice can present relatively authentic simulating results on system's fracture propagation underlying outward stretching effect.

2. Truss structure system is of inferior deformation capacity, so unlike ability of bending in beam with 6 DOF, its components simultaneously break in an instant before global system collapse.

3. Escalated elasticity of bifurcate tri-clawing components in truss system, it has rarely strength improvement along the whole scope but obviously decrease after amplification factor over 6. On the contrary, beam system can obtain desired simulation consequences either on strength or toughness to prevent fracture propagation.

4. For optimization perspective, both systems could obtain optimal reinforcement of fracture prevention by ratio 2. On the contrary, that of beam counterpart could be awarded prominent improvement at level 10 specifically.