Interim Report 2 SURF 2025

Kensuke Shimojo

Progress

There was great progress on designing and manufacturing the experimental setup. We designed a 3D printed interface between a linear stage and a piezoelectric actuator, such that its position and therefore tension on the ring block chains can be precisely controlled. The actuator is now driven by an Agilent 33220A signal generator and a Piezomechanik LE150 amplifier, such that the actuator can send in mechanical impulses in any desired waveform for a given experiment. The actuator is directly connected to a chain of ring blocks (also 3D modeled and printed), where some houses a piezo force sensor glued in. Readings from these sensors from an Agilent InfiniiVision DSO-X 3014A oscilloscope allowed for data collection. On the opposite side of a chain, we designed a 3D printed boundary block bolted into the table with a slot housing another piezo sensor, so we can investigate the pulse behavior at the boundary as well.

In parallel, we accomplished several tasks that adds more options to the experimental setup. After outsourcing to manufacturing companies, we obtained and tested ring block chains made of different materials, including polycarbonate and aluminum. We also extracted triaxial accelerometers from an old experimental setup that we could potentially use to detect mechanical displacements in the blocks, especially in multiple modes. By 3D printing a junction ring and using more linear stages with boundary blocks, we additionally created a junction setup where multiple 1D chains are linked at different angles to each other. This setup was previously investigated through simulation, such that collecting empirical data to compare with the theory is desirable.

Observations and Problems

Data from PLA Ring Blocks

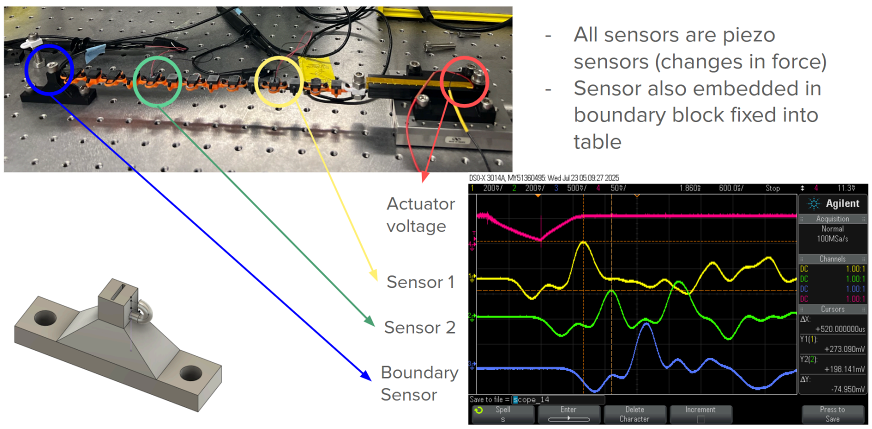

Fig 1: Signal data collected from the oscilloscope and the experimental setup, where the vertical axis represents voltage and x axis represents time (600us per increment). The red signal indicates voltage passed into the piezo actuator for the driving impulse. The yellow signal represents compressive (positive V) and stretching (negative V) forces experienced by the piezo sensor closest to the actuation point, the green signal corresponding to the second closest sensor, and the blue signal showing readings from the boundary block's piezo sensor.

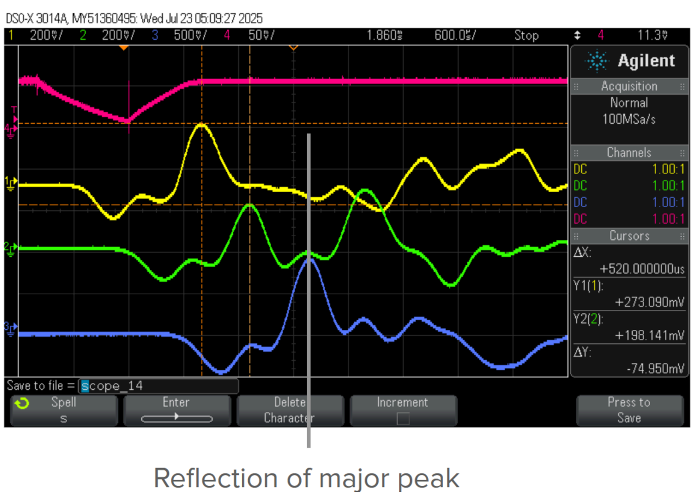

Fig 2: Data collected from PLA ring blocks, where we see a clear compressive peak signal traveling through the different sensors at different times. The reflection at the boundary is also visible as indicated by the vertical line.

Using the setup as shown in Fig 1, we saw very clear and large voltage peaks using the PLA ring blocks (Fig 2). These peaks should indicate the soliton pulse traveling through the ring blocks, and by examining the peak time across different sensors, we can determine the velocity and other attributes of the soliton. Based on rough data collection, the experimental pulse velocity (206 m/s) was reasonably close to the theoretical pulse velocity (195 m/s) for PLA.

What was not expected was how exactly the peaks appeared, especially with regard to the other peaks surrounding it. The actuator voltage is supplied such that the actuator is in an extended state, quickly contracts, momentarily pulling on the ring blocks, then re-extends. This should lead to two peaks: a negative peak for increased tension force during contraction, and a positive peak for decreased tension (higher compression in a sense) during re-extension.

However, we see a small additional peak in between. This may be due to how the piezosensors' only measure the change in applied force, and so its signals decay to 0 after an extended period of constant force. It is possible that the time of approximately constant tension force in between contraction and re-extension was significant compared to the decay time of the signal, such that the signal decays a little before the re-extension is experienced. This would still not fully explain the additional peak, but the signal decay time and the exact feature measured by the piezosensors should be investigated. In this regard, it is also favorable to test and investigate using the triaxial accelerometer instead, as it may give a more direct measurement of the mechanical pulse.

Another limiting factor we found was the actuator's actuation time. Because its voltage is directly proportional to its displacement, it has a limited actuation speed and voltage change over time. Even when a square impulse is sent in, we get a more triangular pulse where the slope of the triangle is the maximum change in voltage over time, especially for higher amplitude changes and shorter impulse times (as seen in Fig 2's red signal). This limits the combinations of displacement vs time we can test. Improving the electrical connection to the actuator may improve this speed.

Other Ring Block Materials

For different materials, we saw a surprising amount of noise and smaller "peaks on peaks" that made measurements more difficult. This was likely due to different impulse parameters required for a large, smooth signal, as well as the rougher surfaces and contacts due to differences in materials and manufacturing processes.

However, in looking for an impulse optimized for the aluminum blocks, we noticed a natural ringing frequency of about 400 Hz on the boundary block. When sending in a sin wave of the same frequency through the actuator, we got a significantly increased signal from the boundary sensor as a very smooth, high amplitude sin wave response, almost like resonance. This shows potential for further experimentation using this setup.

Junction Setup

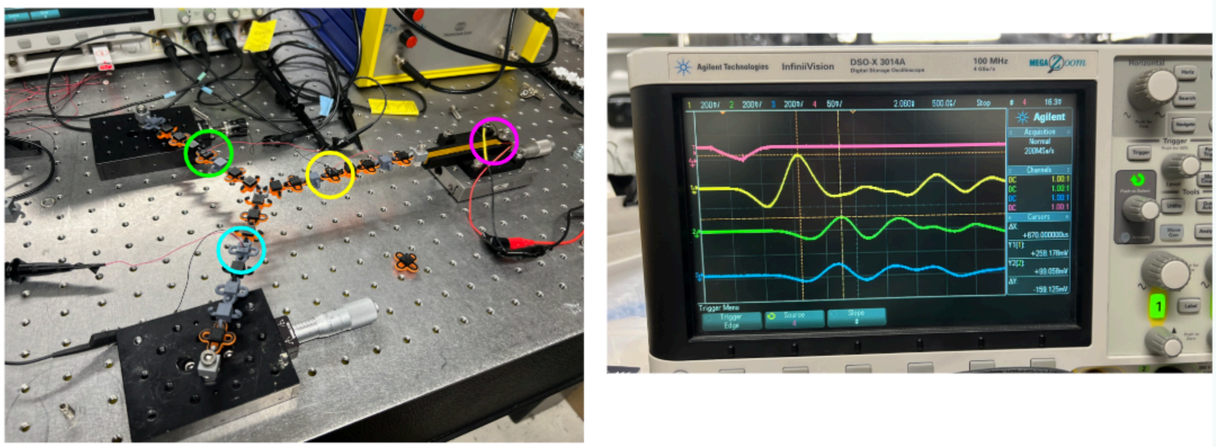

Fig 3: The junction setup (left) where 3 chains meet at one ring-contact junction, where a pulse is sent through one chain towards the junction and splits towards the other two chains. There is a piezo sensor block included in each chain where it is circled, which is read through the oscilloscope (right).

Finally, we tested a simple junction setup as shown in Fig 3, where the 3 chains are adjusted to be approximately 60 degrees against each other. This adjustment is accomplished using the linear stages at the end of The readings from the sensors showed how the pulse amplitudes would split as expected, nearly in half as the chains symmetrically split into 2. It will be interesting to see how the amplitudes and velocities change through the junction for different angles, given the amplitude-dependent propagation of solitons.

Remaining Goals

Our goals now are to integrate a tension force sensor into the actuator and boundary setup to more accurately control the pretension, to conduct more rigorous data collection and signal analysis for comparison with simulation results, and to collect data with the junction setup across different angles of separation. The next major milestone is to build the setup for a 2D PAM mesh to investigate how solitons and nonlinear waves propagate in higher-dimensional structures.

While the overall goals and milestones have not changed, the focus somewhat shifted from aiming to build this setup for a specific experiment or investigation to creating a platform for a more general range of possible experiments we could do in the future. Especially with regard to 2D PAMs and different modes of actuation, we have already seen potential for several possible experiments to be done with PAMs using this setup. While it would be great if one of them could be accomplished and demonstrated with this project, the most significant accomplishment with this project appears to be the generalizability and potential for various experiments of this setup.