Spiketon Amplified Actuator (Spike AA1)

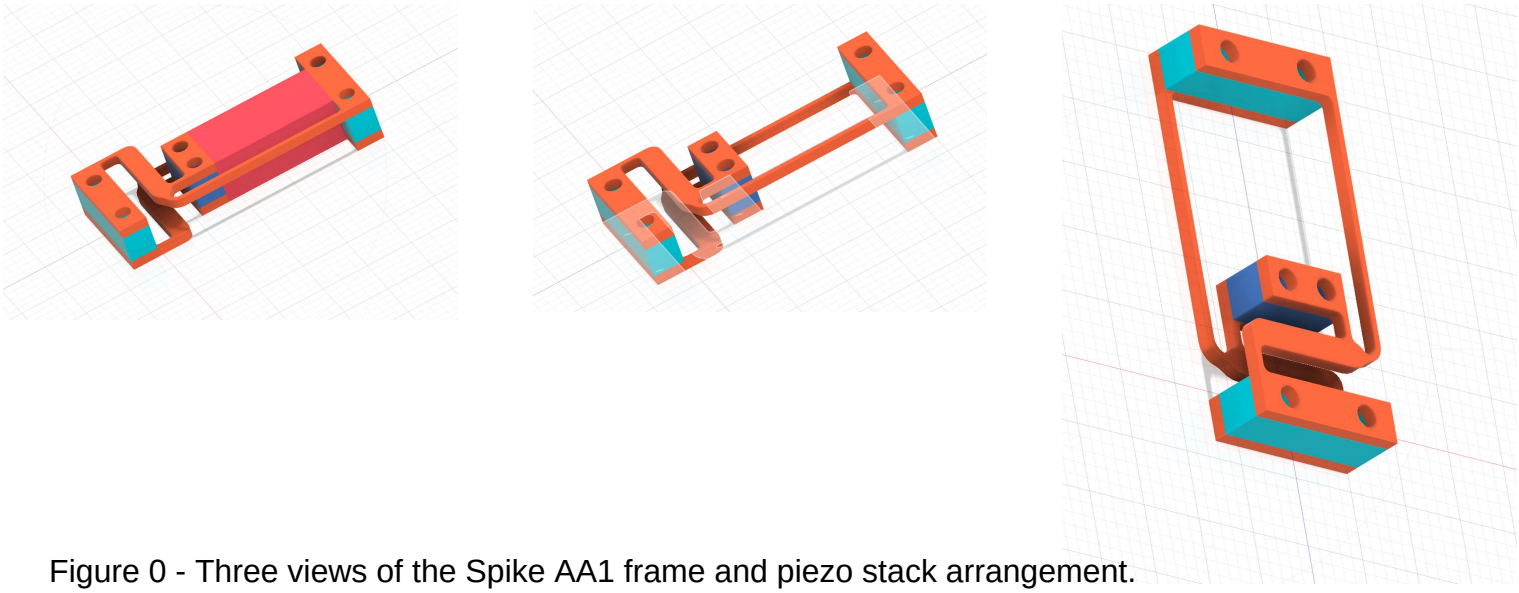


Figure 0 - Three views of the Spike AA1 frame and piezo stack arrangement.

Spike AA1 is a compact amplified actuator designed to dramatically boost the tiny movements of a piezoelectric stack into useful, macroscopic displacements. At the heart of this design is a principle of mechanical amplification that transforms microns into millimeters - and complexity into simplicity.

Structure and Materials

The actuator consists of:

- A frame made from two identical flat metal parts.
- A piezoelectric stack, placed between two inner plates of the frame.

The two flat frame components are joined using bolts or rivets through holes at their ends. Between these plates are metal shims, which create a controlled spacing - the thickness of the shims determines the gap between the two frame layers. The piezo stack, though not shown in the video, sits snugly between the inner plates and expands slightly in height when activated.

Amplification Principle

A typical piezoelectric stack can expand by about 0.1% to 0.2% of its length - an extremely small change. However, in the Spike AA1 architecture, this tiny vertical movement is mechanically amplified by a factor of 10× or more, causing the overall actuator to elongate by around 1% of its height.

The mechanism relies on elastic deformation of the frame. When the piezo stack presses against the plates, the whole structure flexes, and leveraged movements magnify the displacement.

Simulation and Visuals

The accompanying simulation video was created in SolidWorks, which includes a "dramatized deformation" mode. This exaggerates structural bending for clarity - a kind of engineering Hollywood. In reality, the displacements are more subtle, but still significant and functional.

Why Miniaturization Matters

The compact size of AA1 (and its successor, AA2) is not just an engineering curiosity - it's the key to unlocking a new class of electromechanical systems.

- From microns to millimeters: Micro-scale piezo movements are difficult and expensive to manufacture due to the need for ultra-precise tooling. But if these micro-motions are amplified into millimeter-scale displacements, simpler and cheaper production methods become possible.

- Mass-market access: Most piezo-based systems remain trapped in slow, ultra-precise, high-cost niches. Spike AA1 opens the door to affordable, fast, and scalable applications - without sacrificing accuracy or repeatability.

Can Spike AA1 Replace a Standard Piezo Stack?

Yes - Spike AA1 can replace a conventional piezoelectric stack of the same size in many designs. For example, in the central section of the Spiketon M1 actuator, the piezo stack with spring-loaded supports can be replaced by Spike AA1 (or its successor, AA2).

Such a replacement makes sense when the speed of motion is more critical than the force applied by the actuator. A standard piezo stack of the same length typically cannot achieve large step displacements. As a result, the overall speed of motion becomes severely limited.

By contrast, Spike AA1 uses mechanical amplification to extend the displacement range significantly. This enables much faster motion - even if the force per step is reduced - making it an ideal option for systems where agility and response time are more important than brute force.

Design Limitation of AA1: Torsional Distortion

One challenge in the design of Spike AA1 comes from how the internal forces are transmitted through the structure. When the piezoelectric stack expands, it pushes against the upper and lower inner plates, causing the overall frame to expand vertically through elastic deformation. However, due to the diagonal path of force transmission from the flexing plates, a small amount of torsional twisting can occur in the actuator.

In many applications, this torsion is negligible - the surrounding mechanical assembly constrains the actuator and prevents visible twisting. But in some precision-sensitive contexts, this torsional distortion can affect accuracy or alignment.

This limitation is eliminated in the improved version, Spike AA2, which includes geometric and structural refinements that suppress torsion even under high loads.

The twisting effect is illustrated in the simulation video using exaggerated deformation mode. In real-world use, the distortion is minimal and would likely go unnoticed without this visualization.

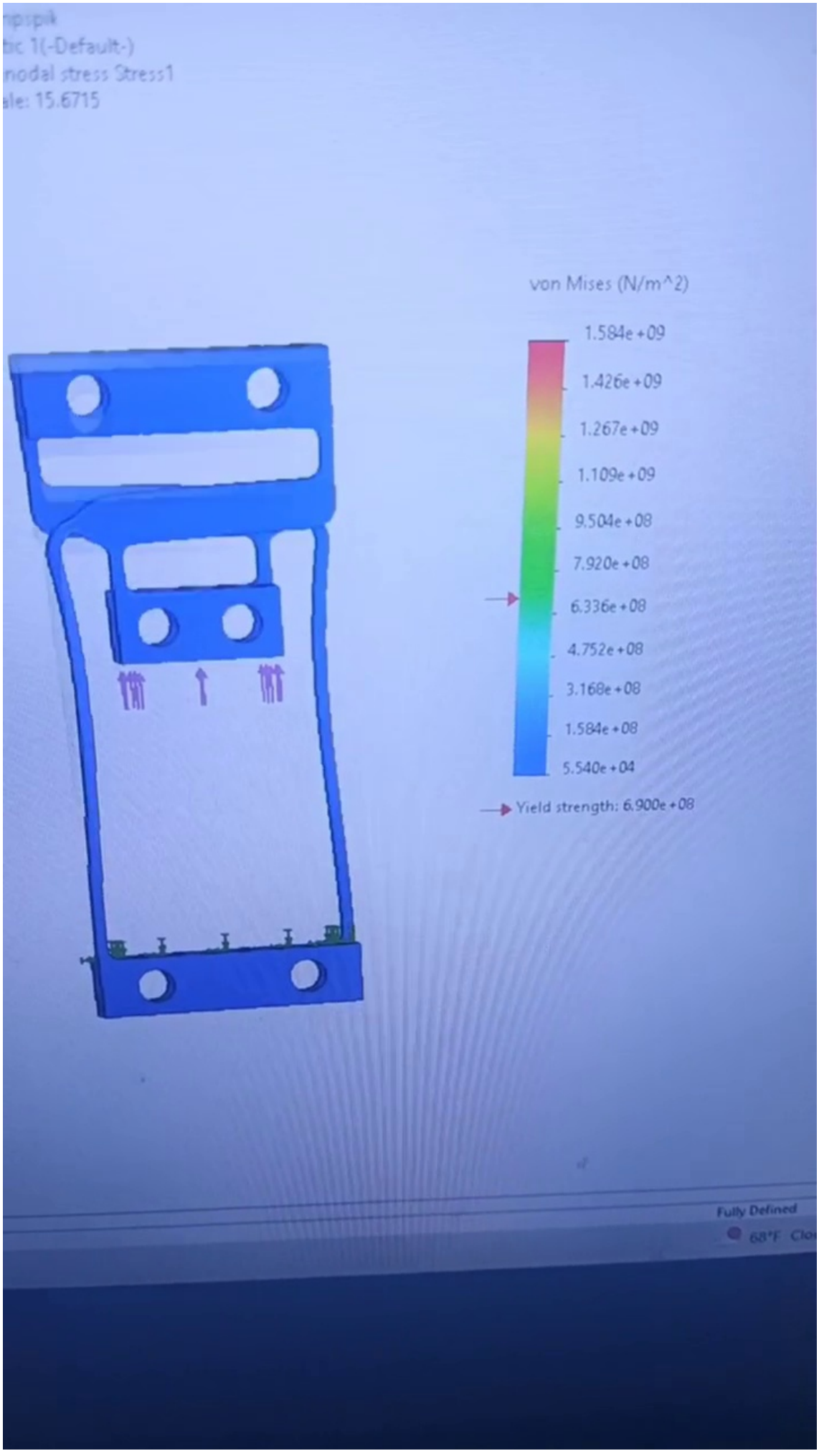
Applications and Outlook

Amplified actuators like Spike AA1 could be integrated into:

- Small walking robots
- Precision pumps and valves
- Lightweight medical devices
- Space-grade micromechanical systems

Its simplicity, compactness, and amplification efficiency make it ideal for environments where space is tight, energy is limited, and precision is vital.

Video 1 - Amplified Motion


nodal stress Stress1
von Mises (N/m^2)
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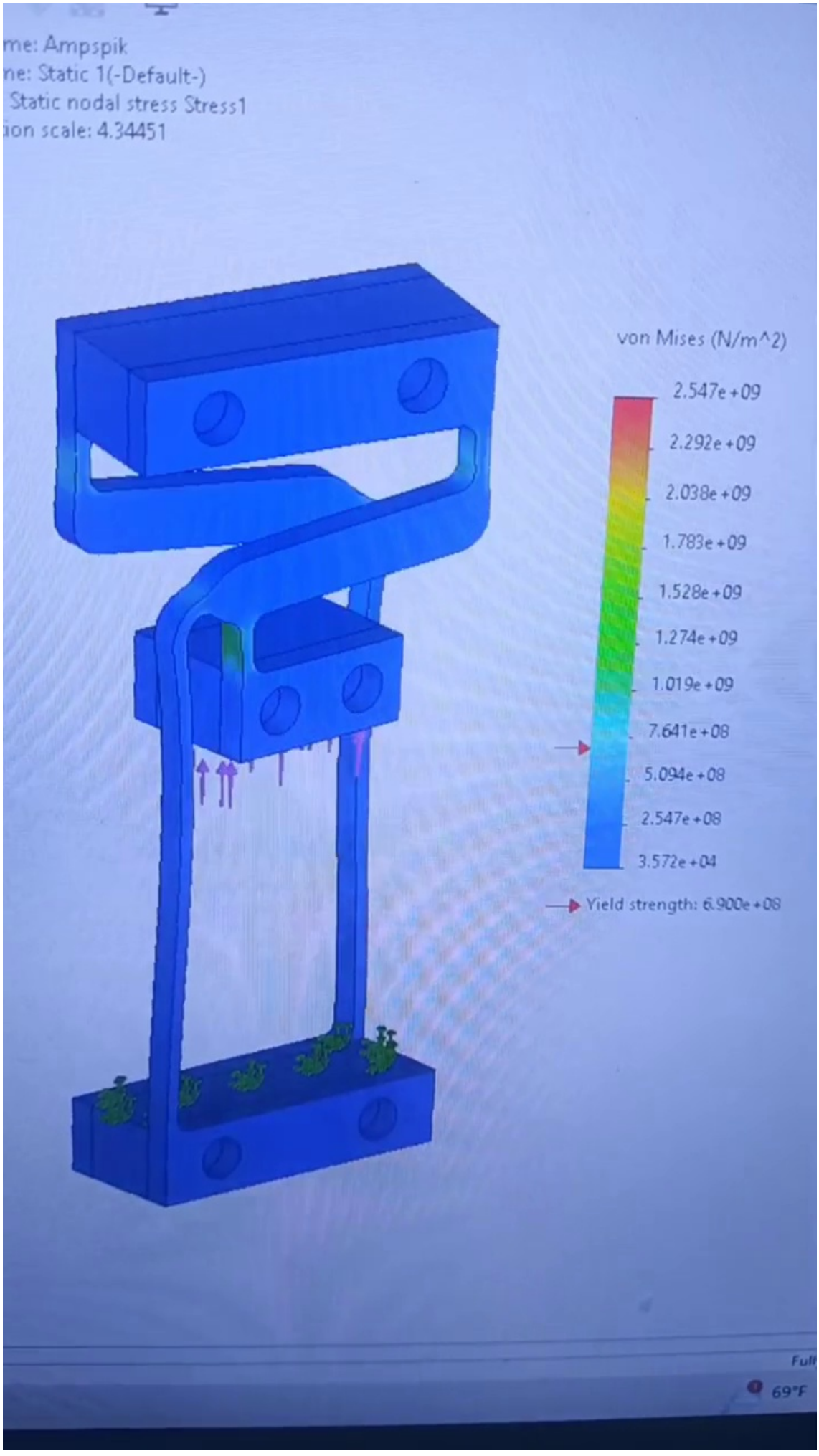
1.426e+09
1.267e+09
1.109e+09
9.504e+08
7.920e+08
6.336e+08
4.752e+08
3.168e+08
1.584e+08
5.540e+04
Yield strength: 6.900e+08
Fully Defined

Figure 1 - Spike AA1 in action: amplified vertical motion.

video1.mp4

Video 2 - Torsional Distortion (Exaggerated)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ne: Static 1(-Default-)
Static nodal stress Stress1
ion scale: 4.34451
von Mises (N/m^2)
2.547e+09
2.292e+09
2.038e+09
1.783e+09
1.528e+09
1.274e+09
1.019e+09
7.641e+08
5.094e+08
2.547e+08
3.572e+04
Yield strength: 6.900e+08
69°F

Figure 2 - Exaggerated torsional twist in Spike AA1.

video2.mp4

Video 3 - Torsional Distortion from End View

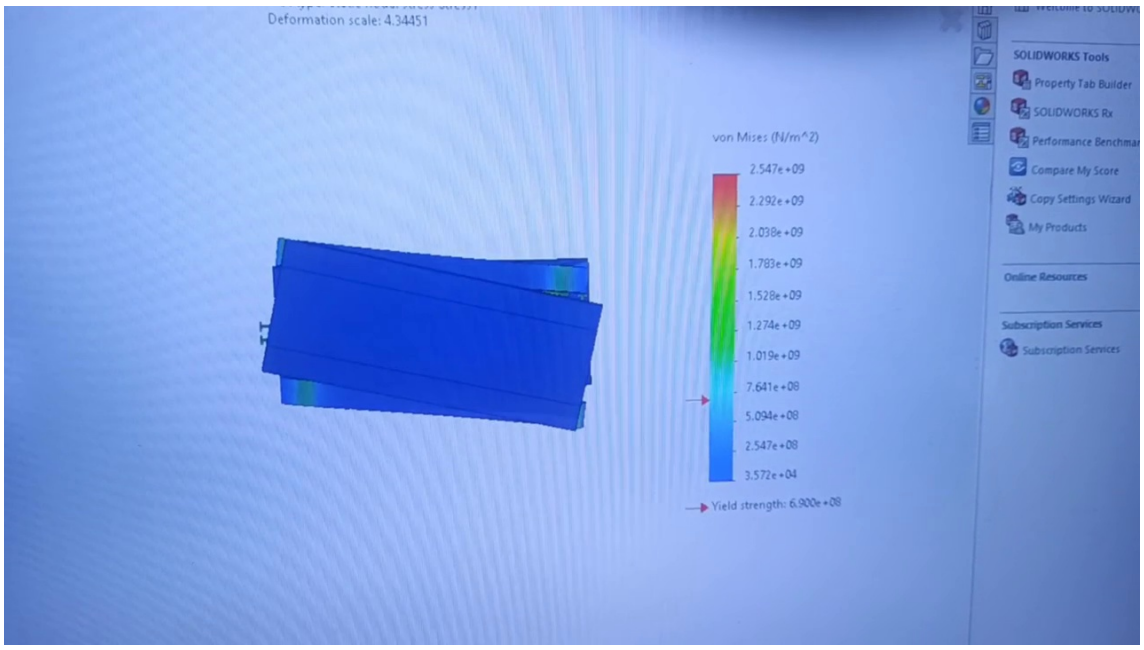

Figure 3 - End-view of torsional distortion in Spike AA1.

video3.mp4