**Granular Jamming**

**Testing**

The 3D printed granular jamming prosthetic hand includes granular jamming technology. The concept of granular jamming is that small particles in a flexible container become rigid when they are tightly packed together. Granular jamming application makes the hand capable to pick relatively small objects. Picking up objects is done by pressing a pad on the object, jamming the granules by use of a vacuum sucking air out of the pad, and then lifting the object with the pad.

To verify plausibility of applying granular jamming technology to the fingers and palm of the prosthetic hand, a simple test was done. The test materials included balloons, coffee grounds, plastic beans, coffee filters, a vacuum, and objects to be picked up including a pen, pill container, and a glass.

Procedure is the following:

First, a balloon was filled with plastic beans so that the balloon is about 60-70% filled. A second balloon was also filled to the approximate level with coffee grounds. Next, the vacuum hose was covered with a coffee filter. Then, the balloon was stretched over the vacuum hose which is covered with a coffee filter. The balloon was pressed on to various objects, and the vacuum was turned on. The balloon was then raised to see how well the balloon would pick up the object. This was then repeated with the balloon filled with coffee grounds.

**Technical Analysis**

Several things were observed during testing. First, the team saw first-hand that granular jamming can and is able to pick up various household object. Additionally, it was determined that coffee grounds were better for picking up objects than the plastic beans. This is because the granule size of ground coffee is smaller than that of the plastic beans. Particles can more easily wrap around an object the smaller they are, so coffee grounds are a better option. Finally, it was observed that the balloon could only pick up objects it was able to have a lot of contact surface area and wrap well around the object. This observation led to a change to the layout of the granular jamming pads. Originally, pads were to be in various parts of the fingers. After the above testing, the team determined that there will only be one large jamming pad in the palm of the hand, because it will have enough surface area to better pick up objects.

After doing this testing the team needed some specifics on the operations of the granular jamming system. Based on (Universal robotic gripper based on the jamming of granular material

Eric Browna,1, Nicholas Rodenberga, John Amendb, Annan Mozeikac, Erik Steltzc, Mitchell R. Zakind,

Hod Lipsonb, and Heinrich M. Jaegera), a change of pressure of 75 KPa was able to pick up objects. The team found a pump for sale with this pressure differential. Using this, the team found the diameter size tubing that would be needed to hold up an object. The following shows the details.

**Force on object**

Assuming object to be held is 1 lb (0.453 kg)

ΔP= 75kPa

F=P\*A

0.453kg=75000Pa\*(πr2)

Diameter=8.7mm - 10mm standard tubing will be used.

Next the team wanted to make sure that the amount of time it takes to remove air from the pad would not be too long, so we calculated evacuation time using specs from the pump chosen.

**Evacuation time**

q = 3.659\*10-5 m3/s

V = 3.659\*10-5 m3

P0 =1013.25 mbar

P1 = 266.25 mbar

t = V/q \* ln (P0/P1)

t = 0.652 seconds

Both calculations resulted in reasonable and doable outcomes.