The study of granular fluids using X-ray imaging

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Abstract

To get high resolution in x-ray imaging a point source should be used. By moving the lead away from the camera the resolution of the image was seen. As the lead was moved farther away from the camera the resolution decreased in both setups. To be able to analyze images of granular particles the resolution should be high. When the synchrotron is back up and beam time is available this study will be continued.

Introduction

The applications of soft robots have grown since the use of granular fluids was introduced. Granular fluids are large amounts of small solid particles such as sand or coffee-grounds. The granular fluids are used as a gripping mechanism replacing the need for sensory feedback. The soft robot seen in figure 1 uses a single mass of granular material that, when pressed onto an object, flows around it morphing to its shape. Upon application of a vacuum the granular material contracts and hardens quickly to pinch and hold the object. This is known as the jamming transition. Because the granular particles are so small x-ray imaging can be used to take a closer look. [1]

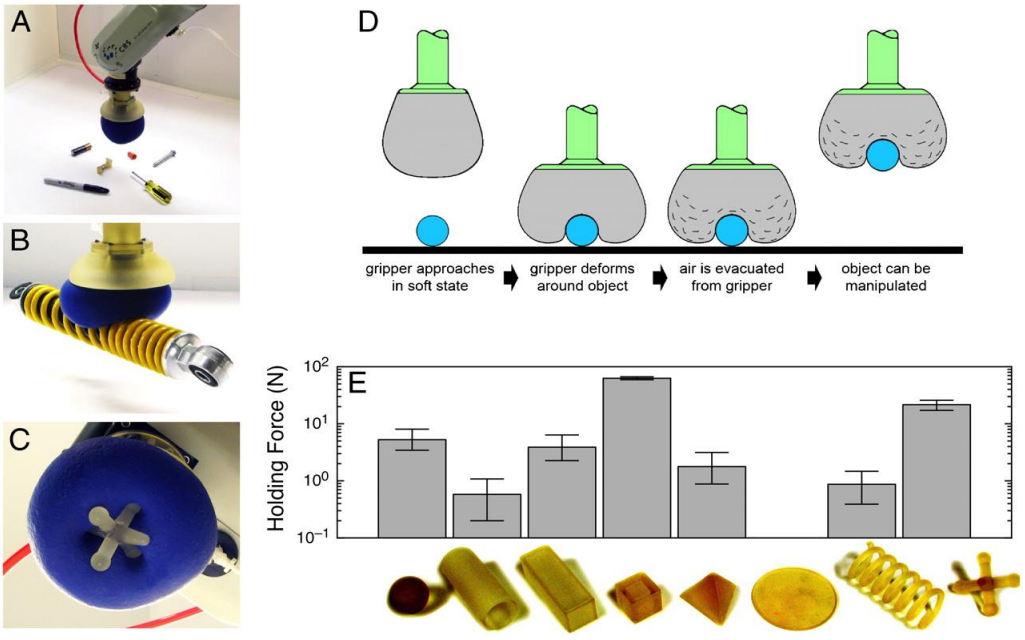

Figure 1: Soft robot using the jamming transition of granular particles as the gripping mechanism [1]

The x-rays that are most common rely on absorption. The object absorbs the incoming rays and casts a shadow creating an image. Density of objects affects the amount of x-rays they absorb. If the density is high, then the object will absorb more rays and vice versa. [2]

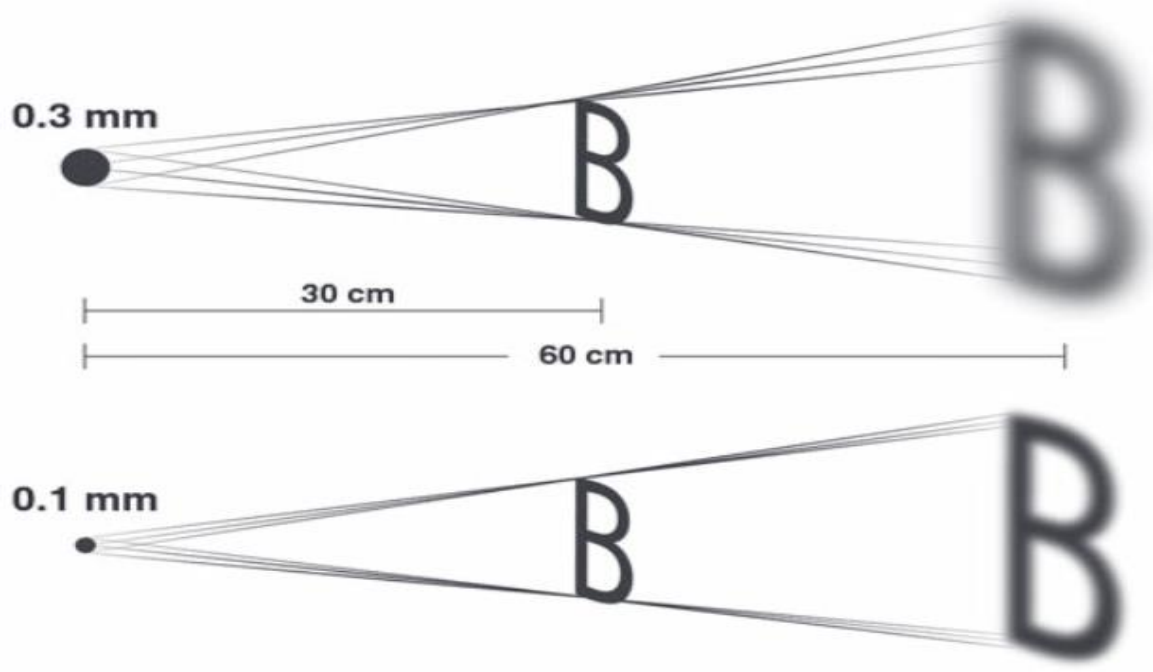

Figure 2: Comparison of x-ray imaging using different sized focal points

The shadow that is cast will depend on the setup. Many factors affect the resolution of the image such as the size of the focal point and the distance the object is from the source. The smaller the focal point the less the image blurs as seen in figure two.

To make advancements with soft robots the flow of granular fluids will be studied using x-ray imaging.

Methodology

An x – ray micro focus tube source was used as the source while two sets of tungsten slits were used to filter the rays. For imaging purposes, the Mercury Detector, Andor Camera, and Matlab were used. The detector helped decipher tungsten rays between copper rays. The camera helped with analyzing how blurry the image becomes by placing a sheet of lead in front of it and collecting images every time the lead is moved away from the camera.

After data was collect from the tube source the beam line was used to image granular particles due to is high x-ray beams. Figure three shows the layout in the beam line.

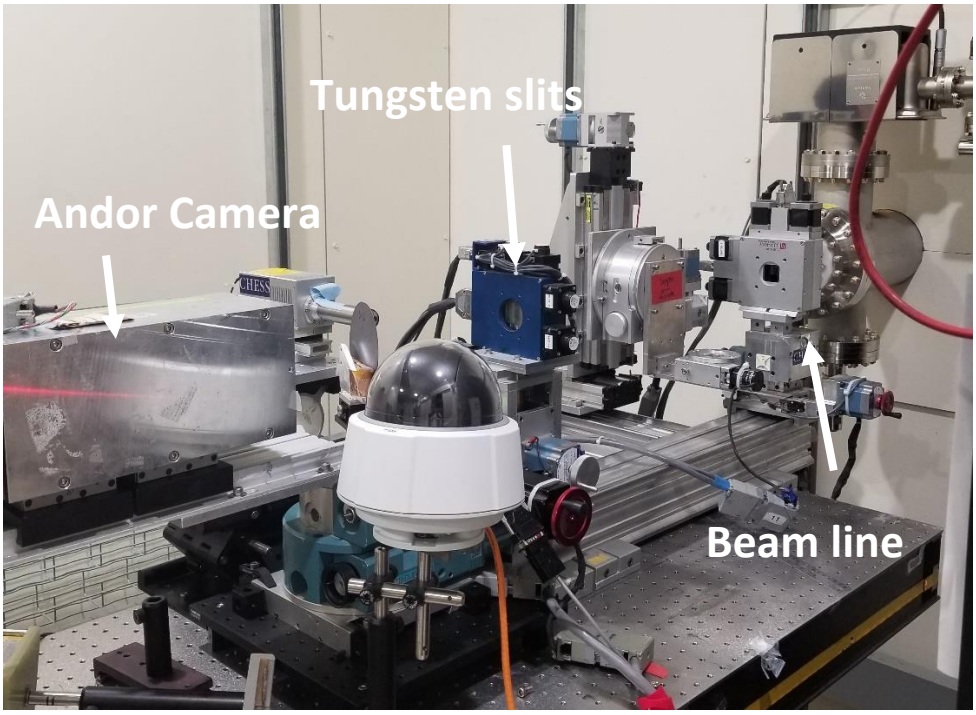

Figure 3: Side view of setup in the beam line

Hutch 3B was used to take the images of the granular particles. The particles were hollow and solid spheres sealed in plastic tubing. They were placed in between the Andor Camera and the tungsten slits. The second set of tungsten slits are downstream in the beam line, not visible in figure three.

Pinhole camera characterization

Using the mercury detector two 2D scans were performed, scans 43 and 44. For the setup of the scans there were two sets of tungsten slits. For scan 43 the dimensions of the first and second set of tungsten slits were 0.2 by 0.2 and 0.72 by 0.72 millimeters, respectively. For scan 44 the dimensions of the first and second slits were 0.1 by 0.1 and 0.358 by 0.358 millimeters, respectively. After each scan was taken the data was inputted into matalab to produce the images seen in figure four.

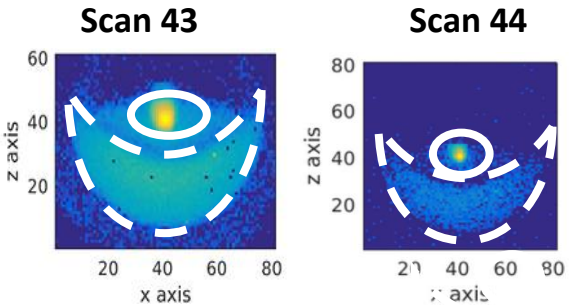

Figure 4: 2D scans of scan 43 and 44

By plotting the sections of the images outlined in the dashed and solid lines seen if figure four, the x-ray energies of tungsten and copper were seen in the peaks of figures five and six. The copper and tungsten graphs correspond to the dashed and solid outlines of the images in figure four, respectively. The copper rays are coming from the setup for the source. There is some copper on the outside of the source.

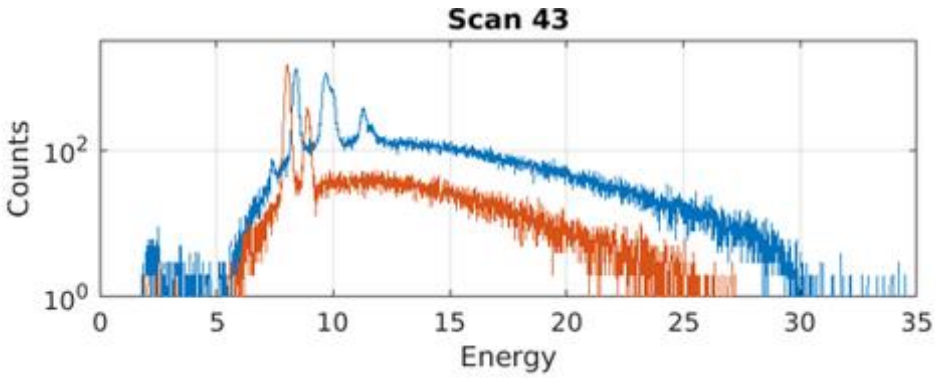

Figure 5: Counts of photons versus energy for scan 43

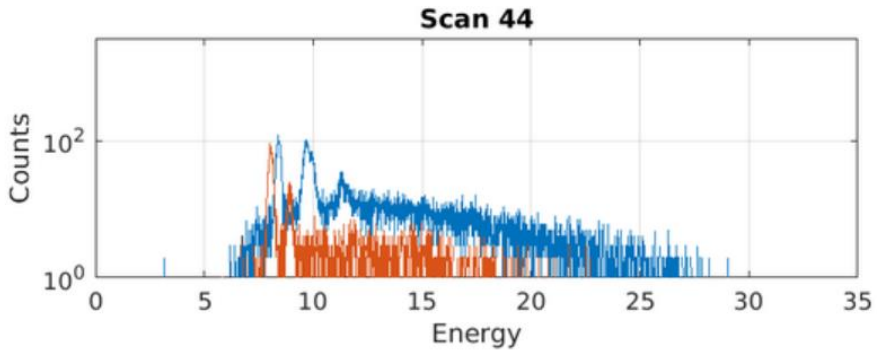

Figure 6: Counts of photons versus energies for scan 44

High resolution radiography

To measure the resolution of the images a sheet of lead was placed in front of the Andor camera. Every centimeter the lead was moved and an image was taken. Fourteen images were collected. In figure seven images of a sheet of lead and an empty glass tube with an outer diameter of 1.5 millimeters placed in front of the camera can be seen. There were two settings for the slits. The dimensions for the slits of the first setup was 0.2 by 0.2 millimeters. For the second setup the dimensions were 0.75 by 0.75 millimeters.

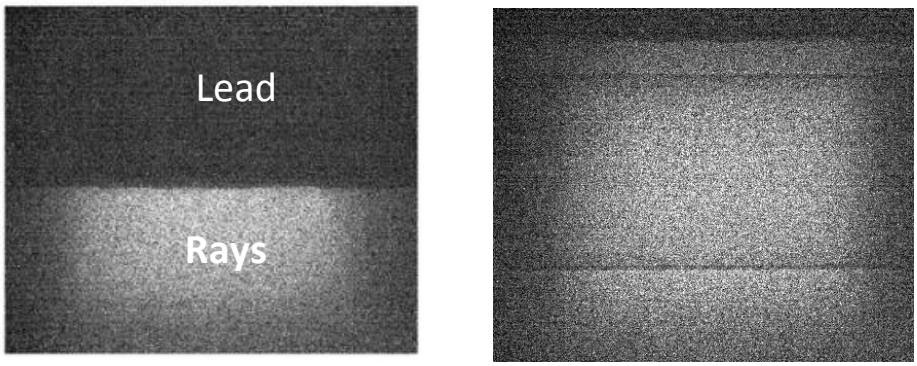

Figure 7: Images of the lead and an empty tube

The graphs in figure eight show the gray value versus distance in micrometers with the lead seven centimeters from the camera. These graphs were created by taking a 200 by 2160 matrix and averaging the rows for the y axis. The matrix was taken from the lead image. The x axis was the distance in micrometers. As seen in the graphs the gray value stays around 1.5, which is lead, until the distance gets to about 1000 micrometers. This steep increase in gray value shows the change from lead to the x-rays.

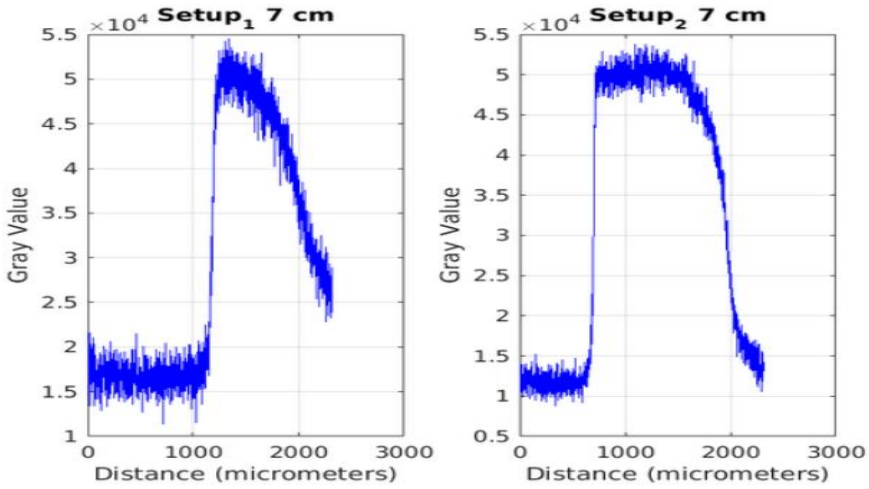

Figure 8: Two gray value versus distance plots both at 7 centimeters away from the camera

Figure nine shows the edge sharpness versus the distance the lead was from the camera. The edge sharpness was obtained by finding the thickness of that steep increase of gray value in figure eight. This was achieved by using matlab. The graph shows the relationship between the resolution of the image and the distance the lead was from the camera. The higher the edge sharpness was the blurrier the images were.

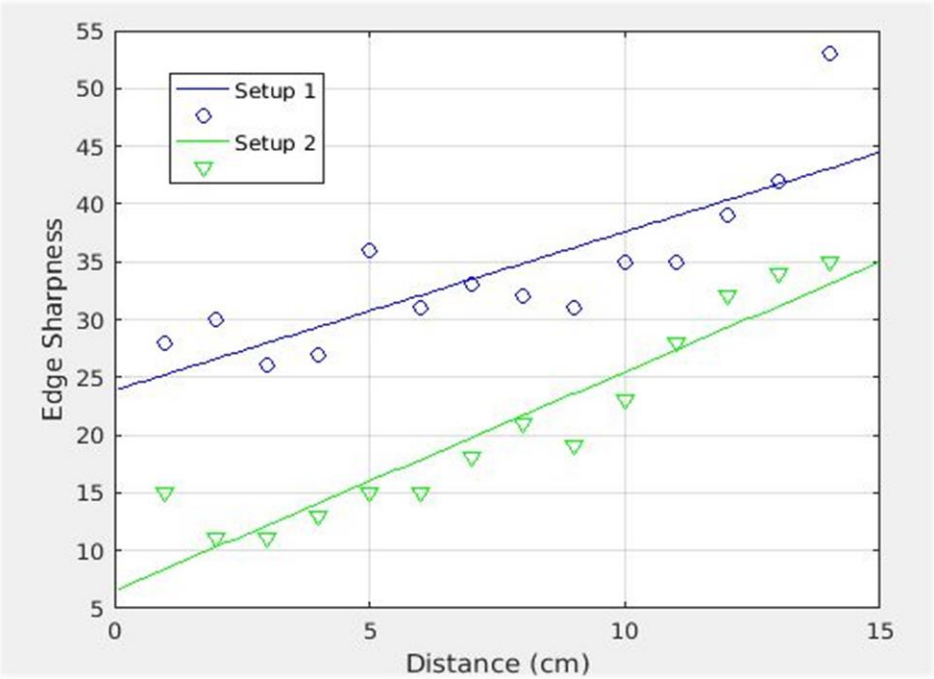

Figure 9: Edge sharpness versus distance from the camera of setup one and two

To get images of granular particles the beam line in hutch 3B was used. One of the images of the granular particles that was taken can be seen in figure ten. To be able to see the particles the magnification of the camera had to be tweaked. Also a better resolution of the particles was collected when the camera was 30 centimeters away from the particles compared to 60 centimeters.

Figure 10: Image of granular particles

Discussion

By reducing the slit sizes in scans 43 and 44 the copper rays reduced as well as the tungsten rays. The purpose of reducing the slit sizes was to filter the copper rays from the tungsten and get a clean point source.

The andor camera was used in capturing images. The lead sheets that were placed in front of the camera were analyzed to determine the resolution. The ending results were that the resolution of the images decreased as the lead was moved away from the camera. For setup one the edge sharpness had a linear fit of $y = 1.3714x + 23.8571$. For setup two the edge sharpness had a linear fit of $y = 1.8945x + 6.5055$. The slopes of these fits are very similar but overall setup two had a better resolution.

By using hutch 3B, images of the granular particles were retrieved. Not a lot of information was obtained due to the limited amount of beam time. This study will be continued when more beam time is available.

References

[1] Brown, E. (2010, November 2). Universal robotic gripper based on the jamming of granular material. Retrieved July 1, 2019.

[2] Greaves, A. W. (2010). Phase contrast in x-ray imaging. Retrieved June 24, 2019.

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