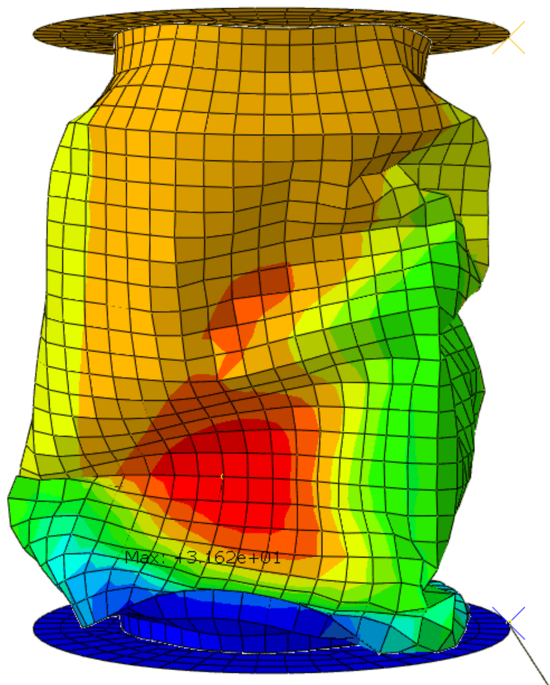
Final FEA Project: Soda Can



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MECH 301A - Finite Element Analysis

Dr. Seth Dillard

Introduction:

The premise of this project is to simulate the displacement of an empty aluminum can being crushed between two surfaces, the bottom of a shoe and concrete or a can-crushing machine. The goal is to compare a simulation of a can being crushed to real-world data to see if an accurate simulation can be made. Soda cans are primarily made up of two types of aluminum alloy: Al 3004 and Al 5182. The properties of these materials that are relevant to this project are listed in Table 1. Al 3004 makes up most of the can being the body while Al 5182 is only at the cans end. Aluminum cans made is the United States generally have a thickness of .097mm for the main body and a lid thickness of .2mm

	Density	Young's Modulus	Poisson's Ratio
Al 3004	2.6-2.8 g/cm^3	70-80 GPa	.33
Al 5182	2.65 g/cm^3	69.6 GPa	.33

Table 1 - Material Properties

There will also be a friction coefficient of 1 that is going to act as a penalty in the simulation. To simulate the crushing of the can, two rigid plates, that simulate the surfaces that will crush the can, are placed at either end of the can. One plate will be completely fixed, simulating the ground, the other will compress the can, stimulating a foot.

Methods:

Since this simulation was tricky to get working, a lot of compromises had to be made. First off the sketch itself had to be simplified a little. Figure 1 and Figure 2 show the changes that were made from what a typical can might look like to what was put into abaqus. The simplified sketch was recreated in abaqus to reduce the potential of errors occurring. Figure 1 is also not a perfect representation of a soda can as it is missing the double seam as shown in Figure 3.

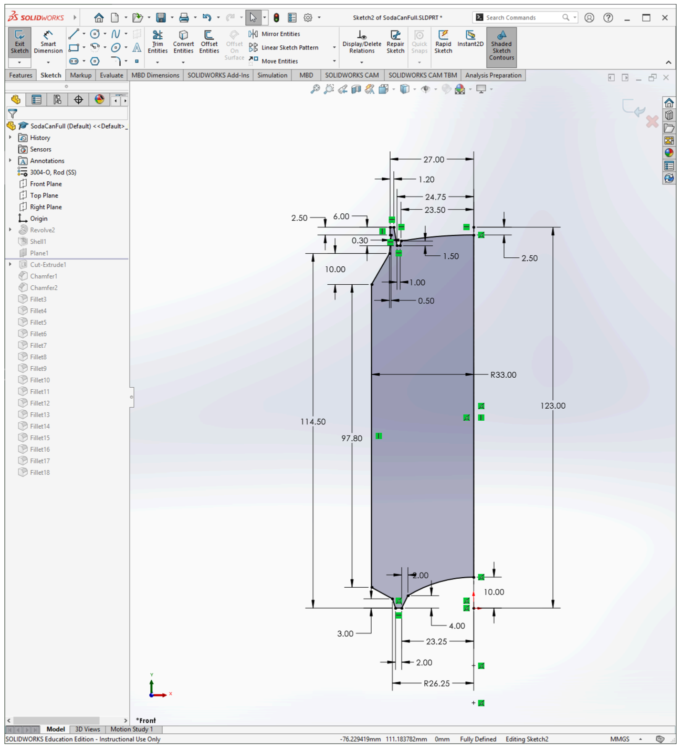

Figure 1 - Can Sketch

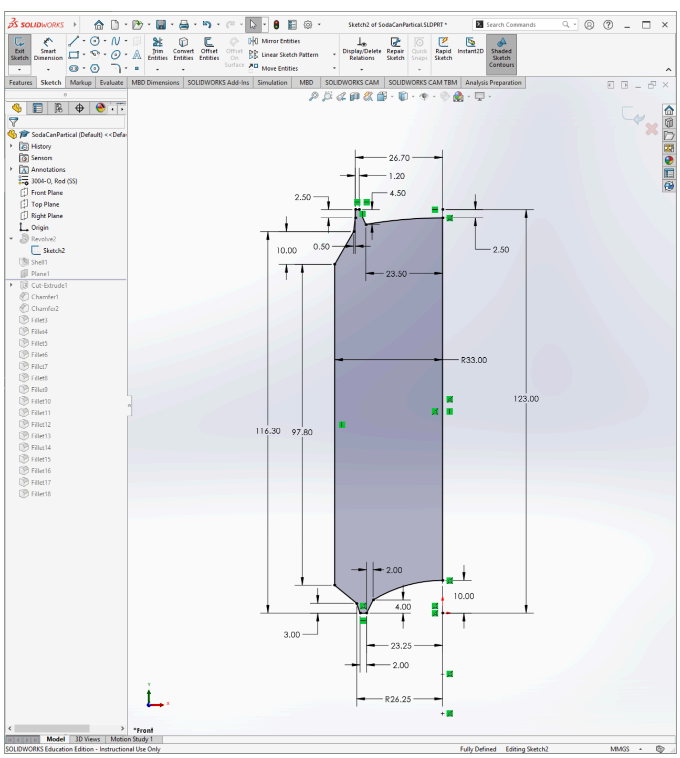

Figure 2 - Simplified Can Sketch

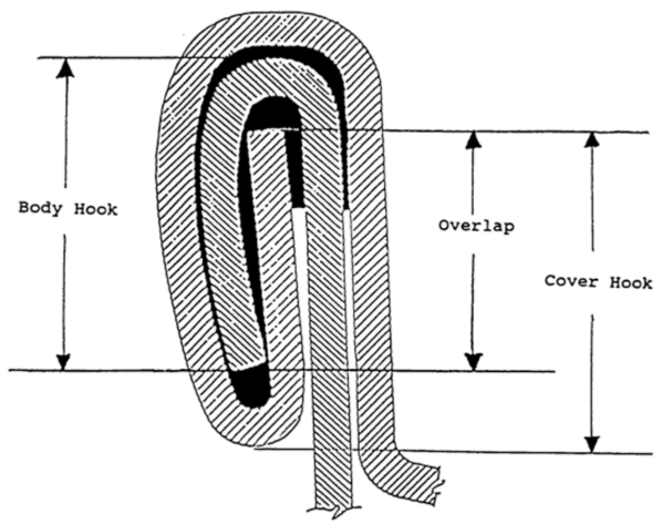

Figure 3 - Double Can Seam

Next compromise is with the thickness and material type used. As stated in the introduction section two types of aluminum alloy are used in can manufacturing. For this simulation only one was able to work, being Al-3004. The thickness also caused issues so it was changed .2mm as some. Since Al-3004 doesn't have a definitive value for the possession ratio and young's modulus, the average value was used.

Some assumptions were the exact measurements of the sketch. Most were estimated using a ruler while others were found by looking up the dimensions. All dimensions were compared to other Solidwork models. The double seam was tricky to 3D model both in Solidworks and Abaqus but the section that contains it is negligible for the experiment.

For simulating the can being crushed two parts were made in Abaqus: the can, and a rigid plate. Both were created using a revolved shell. Next they were assembled having one place at the bottom of the can and another at the top. Al-3004 was the material assigned to the whole part. For the step procedure dynamic, explicit was chosen with the time changed to .1. A friction coefficient of 1 was chosen for interaction properties and created interaction was set to the initial step and general contact (explicit). In field output, S, MISES, E, and ENER we all added. Two boundary conditions were created, one to keep the bottom plate fixed in space the other set to move 100mm down and also requiring a tabular amplitude shown in Table 1 . A topology optimization was also created. Nothing is frozen, two design responses were created one for strain energy the other for volume, and a Constraint value of .3 was used. The mesh for the plate remained unchanged. The mesh for the can changed as shown in Table 2 and an accompanying job was created for it along with their respected elements, nodes, and time duration.

Time/Frequency	Amplitude
0	0
.1	1

Table 1 - Tabular Amplitude

MESH	SEED SIZE	ELEMENTS	NODES	~TIME (s)	STRAIN ENERGY DENSITY (Mpa)	% CHANGE
1	4	1955	1946	245	165774	-
2	3	3376	3365	420	97696.7	69.68
3	2	7549	7515	1500	129932	24.81
4	1.5	13320	13276	4500	146337	11.21
5	1	29866	29781	17000	102732	42.45
Plate	5	265	286			

Table 2 - Mesh Convergence

Results:

Figures 4-7 show the deformation of the can with respect to time and a seed size of 4. They highlight the areas that receive the most deformation at that specific time. Figures 8-11 show the can deformation at the final time for their respective seed size. Each step in the simulation for the seed sizes was relatively the same with similar data.

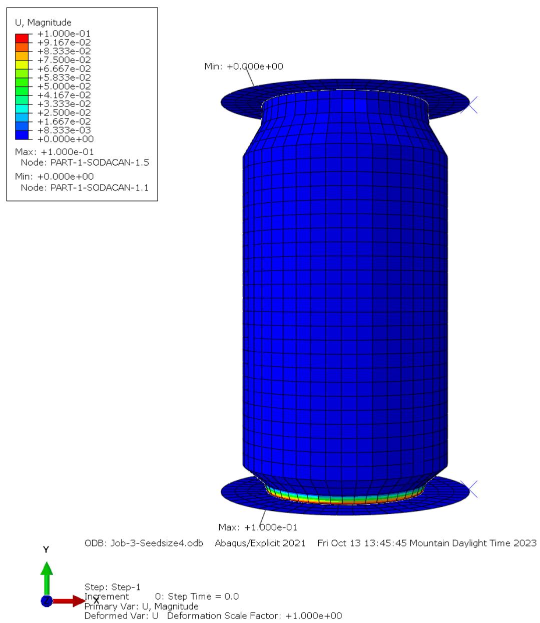

Figure 4 - Seed Size 4: U Magnitude at T Initial

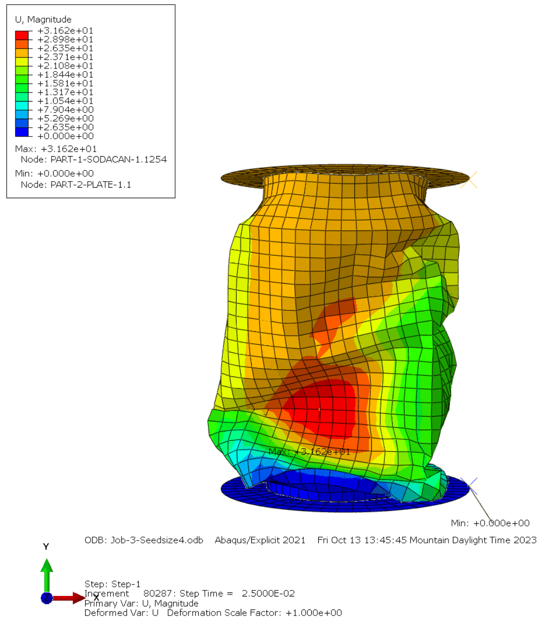

Figure 5 - Seed Size 4: U Magnitude at T2

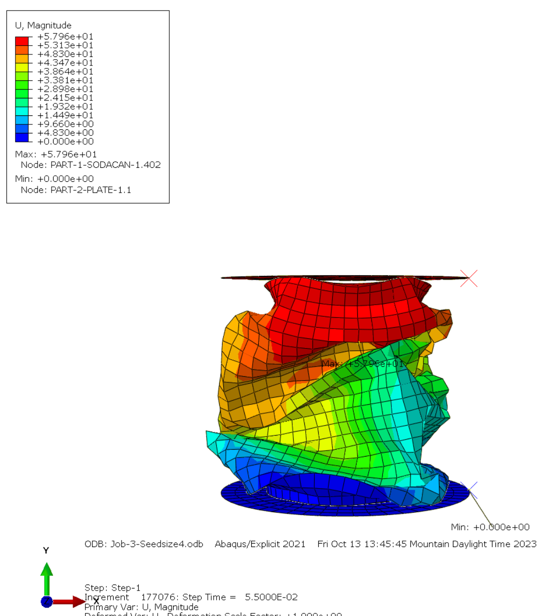

Figure 6 - Seed Size 4: U Magnitude at T3

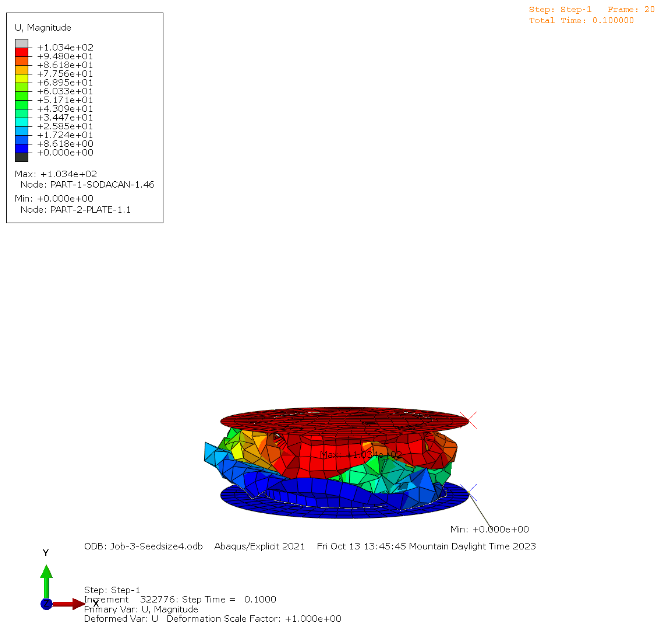

Figure 7 - Seed Size 4: U Magnitude at T Final

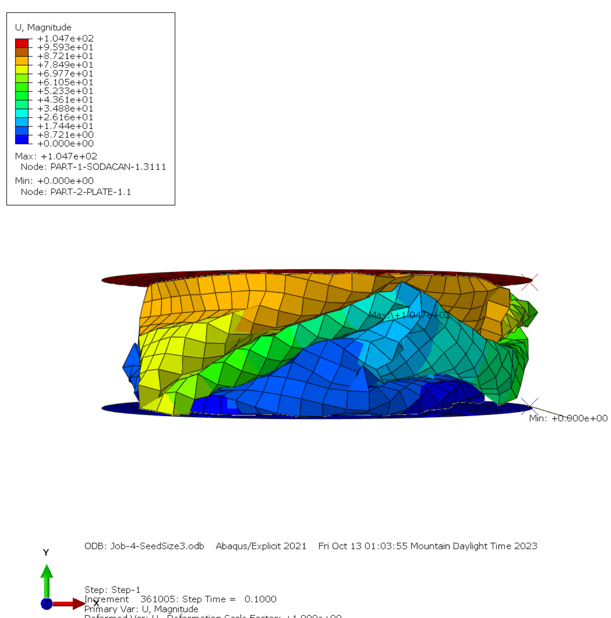

Figure 8 - Seed Size 3: U Magnitude at T Final

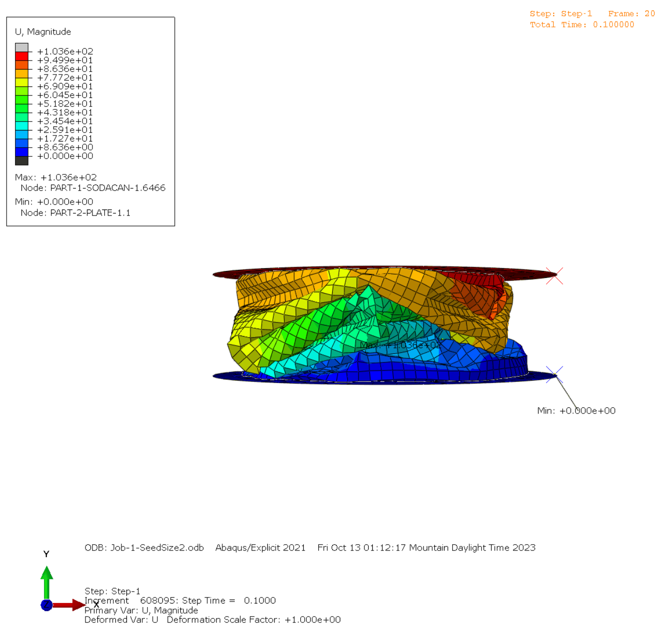

Figure 9 - Seed Size 2: U Magnitude at T Final

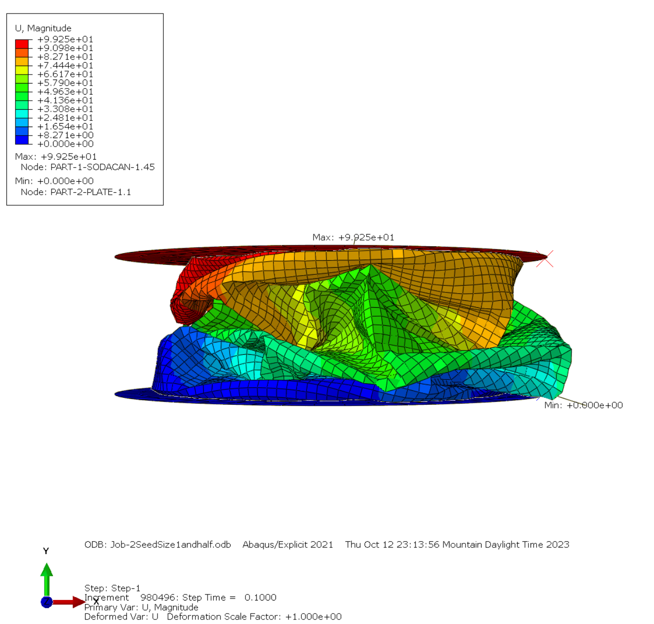

Figure 10 - Seed Size 1.5: U Magnitude at T Final

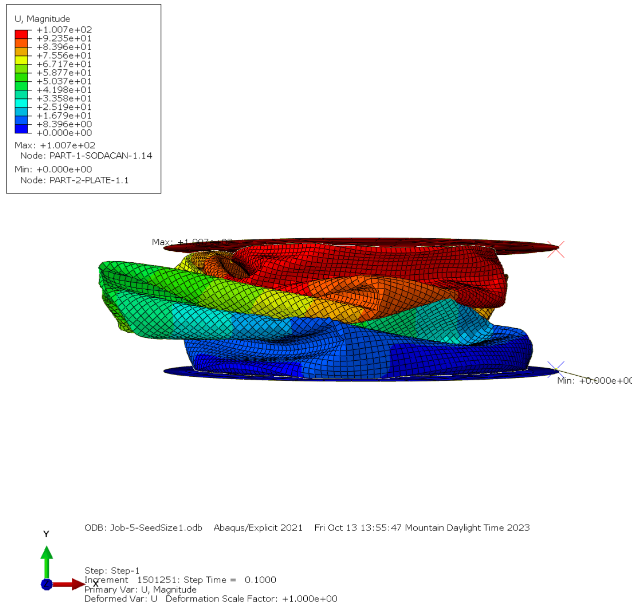

Figure 11 - Seed Size 1: U Magnitude at T Final

Table 2 and Figure 12 shows the mesh convergence data gatherer to validate the simulation.

MESH	SEED SIZE	ELEMENTS	NODES	~TIME (s)	STRAIN ENERGY DENSITY (Mpa)	% CHANGE
1	4	1955	1946	245	165774	-
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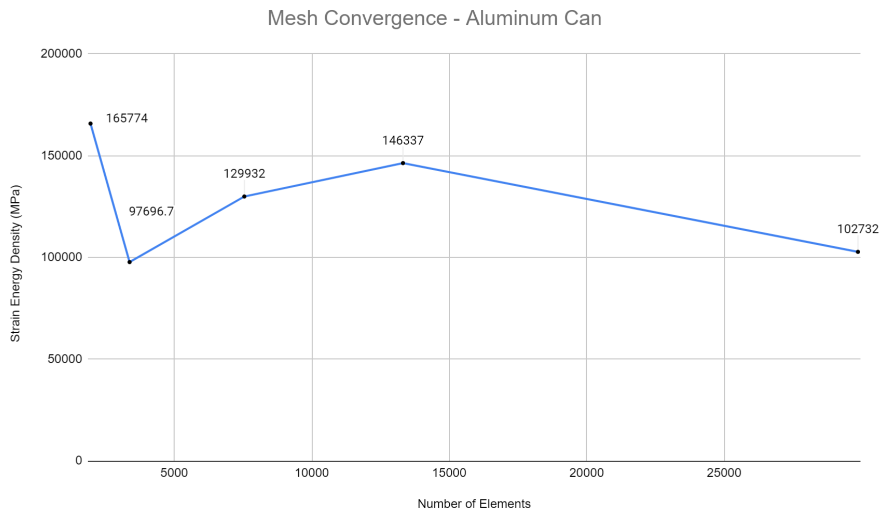

Figure 12 - Mesh Convergence Graph

Verification and Validation:

When it comes to visual verification the simulation did a good job in prorating the displacement of a can will look like. Figures 13-15 represent the best attempts at crushing a can between concrete and a shoe to achieve similar results. When compared to Figures 13-15, Figures 10 and 11 seems to be the most accurate seed size from the simulation.

Figure 13 - Crushed Can 1

Figure 14 - Crushed Can 2

Figure 15 - Crushed Can 3

For mesh convergence, the results didn't go as well. For seed size of 1.5 being the most accurate of the 5 but not being the lowest seed size in the simulation. Mesh 1 had the highest node and element count, as well as the longest run time, but produced results that were far below the expectation. A seed size between 1.5 and 1 will have the most accurate simulation.

Discussion:

Since when you crush a can there are a lot of variables that can impact the results, like any dents. In addition to this the cans crushed in Figures 13-15 Experienced material failure, tearing, while the simulation the can remained intact. For this project around 10% would be a decent validation and 5% would be an ideal case. Even though mesh 4 provided the best results, they are less than great. With that being said, the mesh convergence does show the variability when it comes to crushing a can in that no two results are the same and even the most inaccurate results still provide a view of the difficulty of constantly crushing a can. A major limitation was the time it took to process the model. The last two meshed durations were between about 1 and a half hours to almost 5 hours to complete. Trying to find the point where the mesh convergence is within a tolerable range would prove to be very time-consuming.

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