HU3910 D-Term 2020

Project- The Rail

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Background:

Lester William Polsfuss otherwise known as Les Paul was born in 1915 in Waukesha, Wisconsin. He was a talented musician and a determined inventor set on changing the music industry for the better. Best known for being the father of the solid body electric guitar, Paul achieved this goal and revolutionized the music industry. Yet, Paul did not achieve this task overnight. He was repeatedly rejected and climbed many steps along the way to reach that point. His first electric guitar consisted of pieces of his father's phonograph attached to his acoustic guitar, but the sound did not satisfy him. This caused Les to ruin his guitar by filling it with a plastic like substance because he wanted to hear just the strings vibrate. Paul then found inspiration in an unlikely place, the railroad tracks across the street from his childhood home. Paul collected a 2 foot piece of discarded rail along with some spikes. Paul then took the microphone from his mother's telephone and strung a guitar string over the length of the rail, which crafted a device currently known as, "The Rail". Even though Paul's mother, pointed out, "The Rail" was not a practical electric guitar, hearing the sustain the seemed to go on forever motivated Paul towards his climb to his eventual legendary status. Paul's creativeness and spirit has inspired generations and this project is no exception.

Les Paul's Rail

Goal:

The purpose of our project was to first recreate Les Paul's original rail design, and then to examine how material selection would play a role in determining its sound. To build the original rail, we searched on the internet for as much information about its design and construction as we could find; however, all we could find were a few pictures. Because of the ongoing COVID-19 lockdowns, we needed materials that could be ordered online; railroad rails were only easily available by physically visiting scrapyards. We decided to use an I-beam instead; firstly because it was more readily available, and secondly because we could get identical ones made of different materials from an online supplier.

To examine the effect of material choice, we decided to build 2 prototypes; the first would be a steel I-beam with a string and piezo-electric pickup. Instead of railroad spikes, we used 1in-diameter round bars. The second would be identical in every way, but the I-beam and round bars would be made of aluminum.

Design:

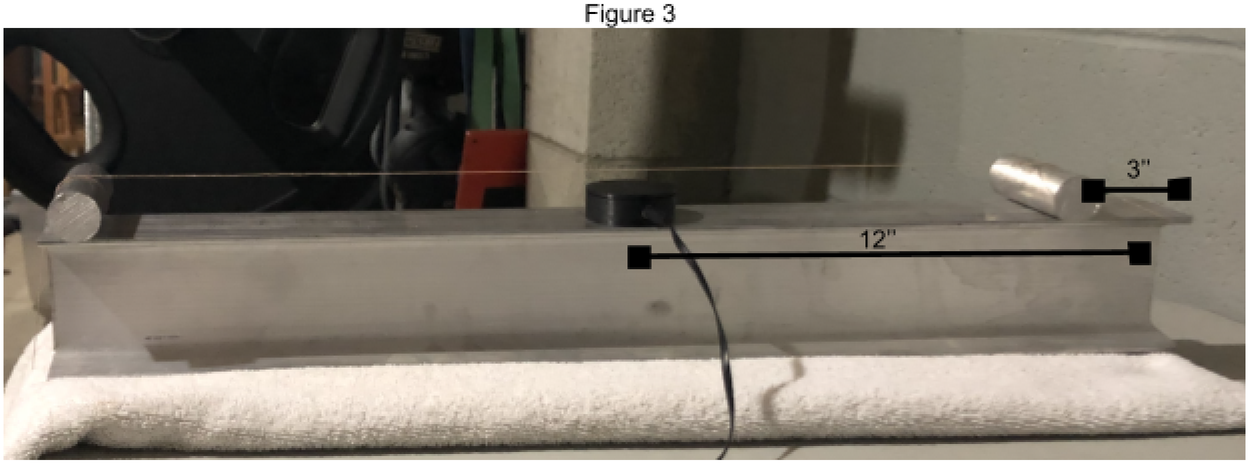
The main purpose of this design was to replicate Les Paul's original rail. Working without the specific budget and the materials available during the difficult times the two prototypes constructed stay true to the spirit of Paul's design. The materials used for this can be best summarized in Figure 1 below.

Figure 1			
Part	Material	Dimensions	Ordered From
I-Beam	Steel	3" X 2.33" X .170" 2' long	MetalsDepot
	Aluminium		
Round bars	Steel	1'' diameter 3'' long	MetalsDepot
	Aluminium		
D'Addario Phosphor Bronze Guitar Strings	Nickel and Bronze	0.022'' diameter (3rd String Green Tag)	Reverb
Adventure Audio Piezo Pickup 2019 Black	NA	1/8" jack	Reverb
5 lb weight	NA	NA	NA
Towel	Cotton / Polyester	NA	NA

While Les Paul's original design did not contain exact measurements, except for the length of track (2ft), the design of our prototypes strayed a bit from the original model to eliminate variables. First, the I-Beam was rested on a cotton/polyester towel to ensure both prototype's results would be mitigated in a similar way. Our initial experimentation showed us that whatever material the I-Beam was resting on affected the attack, decay, sustain, and release. Next, a guitar string with a 0.022" diameter was tied to one end of the I-Beam and rested over the 1st round bar which was placed 3" from that end (Figure 2). The string was then looped around the 2nd round bar, placed as close to the far end as possible, to hold it in place. The pickup was placed in the middle of the I-beam or 12” from either side. This can all be seen in Figure 3 below.

Figure 2

Figure 3



Placing the second round bar at the far end of the I-Beam was different from Paul’s original design, but it ensured the string would not rest on the I-Beam and allowed each prototype to have equal tension on the guitar string. After the string was looped around the second round bar it was tied to a 5 lb weight as seen in Figure 4. This designed element eliminated the variable tension, allowing our analysis to focus on the difference in materials. Initially, our design had some flaws. We ordered round bars that were too small to hold the guitar string over the pickup as seen in Figure 5; however, new round bars ordered with 1” diameters accomplished fixed this issue.

Figure 4

Figure 5

Protocol:

1. Tension the string with 5 lbs of force by hanging the weight off of the edge of whatever table or desk the rail is resting on.
2. Pluck the string by pulling it back from the center (directly over the pickup) until it is directly over the edge of the rail, and then release. This ensures that the string is plucked the same amount each time.
3. When the resulting note is no longer audible, repeat for a total of 10 trials.
4. Examine the waveforms in Audacity; measure the length of the attack, decay, sustain, and release regions of each note and record the data.

Results:

After recording signals for both prototypes into audacity each signal was analyzed. The results for the steel prototype can be seen in Figure 6 and Table 1 and for the aluminium prototype the Figure 7 and Table 2.

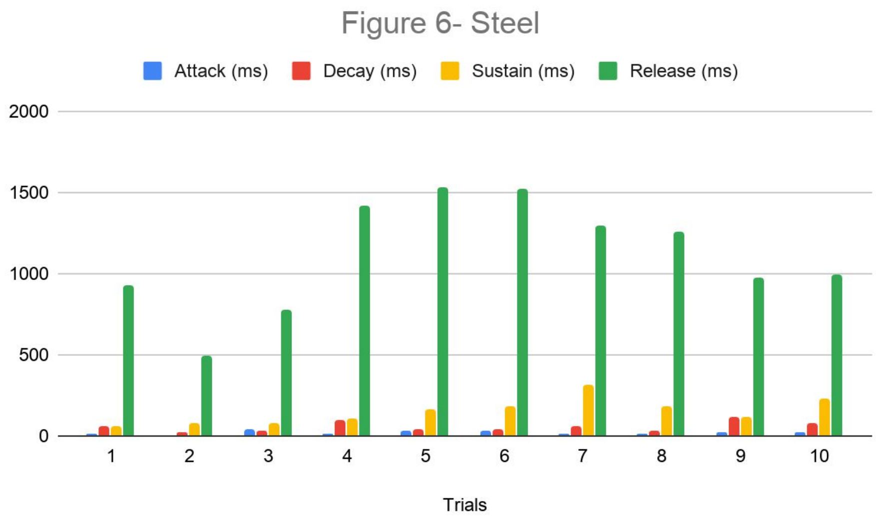


Table 1- Steel Data

Trials	Attack (ms)	Decay (ms)	Sustain (ms)	Release (ms)	A/D	A+D/S	A+D+S/R
1	12	58	64	926	0.207	1.094	0.145
2	7	27	83	493	0.259	0.410	0.237
3	44	28	77	774	1.571	0.935	0.193
4	12	94	110	1422	0.128	0.964	0.152
5	35	44	168	1527	0.795	0.470	0.162
6	30	45	186	1520	0.667	0.403	0.172
7	16	60	313	1292	0.267	0.243	0.301
8	9	30	180	1258	0.300	0.217	0.174
9	23	116	122	975	0.198	1.139	0.268
10	26	78	226	993	0.333	0.460	0.332
Average	21	58	153	1118	0.473	0.633	0.214

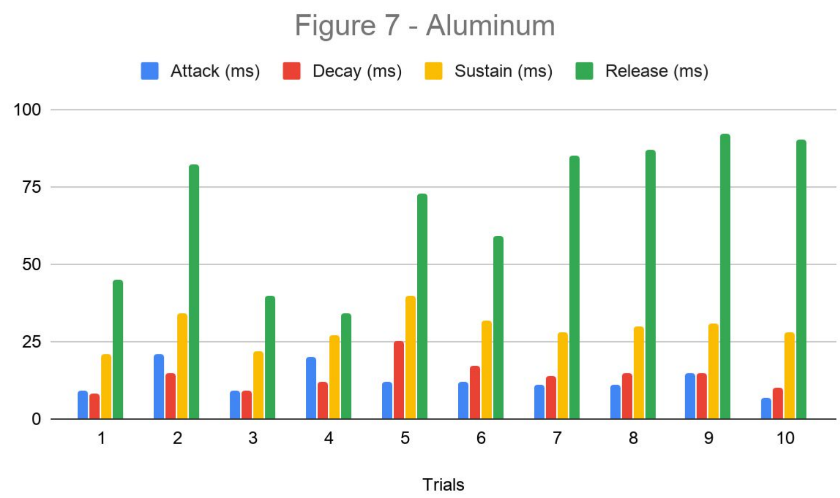


Table 2- Aluminum Data

Trials	Attack (ms)	Decay (ms)	Sustain (ms)	Release (ms)	A/D	A+D/S	A+D+S/R
1	9	8	21	45	1.125	0.810	0.844
2	21	15	34	82	1.400	1.059	0.854
3	9	9	22	40	1.000	0.818	1.000
4	20	12	27	34	1.667	1.185	1.735
5	12	25	40	73	0.480	0.925	1.055
6	12	17	32	59	0.706	0.906	1.034
7	11	14	28	85	0.786	0.893	0.624
8	11	15	30	87	0.733	0.867	0.644
9	15	15	31	92	1.000	0.968	0.663
10	7	10	28	90	0.700	0.607	0.500
Average	12.7	14	29.3	68.7	0.960	0.904	0.815

Analysis/Conclusion:

After analyzing the signals we found that on average, the steel bar had a longer sustain relative to the attack and decay. This was determined utilizing the formula (A+D)/S. The steel bar averaged 0.633, and the aluminum bar averaged 0.904 where a lower value corresponded to a higher relative sustain.

We also found that on average, the steel bar had a much longer release relative to the length of the entire ADSR envelope. We determined this with the formula (A+D+S)/R. The steel bar averaged 0.214, and the aluminum bar averaged 0.815 where a lower value corresponded to a higher relative release.

Based on this data, we have concluded that steel is a more resonant material for a solid-body electric guitar than aluminum; however, we also have to recognize the limits to this conclusion. First, looking into the methodology one has to acknowledge the variety in plucking strength for each trial. On each of the prototypes, a different person was conducting the testing adding a variable to the methods. We would suggest future studies to find a more consistent plucking method. Also, the analysis carried on on audacity had its limits. Audacity is a great free program that can display the signals but the estimated durations from attack, decay, sustain, and release were found through individual interpreting of the signal. A program with capabilities to estimate these values would be better suited for this type of analysis. For future studies utilizing these materials, it may be interesting to vary the tension on the guitar string. This could be accomplished by utilizing a tuner. Also, the results may vary testing guitar strings of different diameters that are available in the materials.