Sustainable Packaging

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Abstract

Every year, the packaging industry makes a significant contribution to the overall waste of the planet because of the various cardboard boxes and different packing materials. This project aims to specifically reduce this type of waste. A sustainable packing material prototype was developed with a focus on material, structure, and design. An Arduino based impact testing device was built and used to compare the packing material prototype to existing packaging solutions. This report includes the process as well as the use for this accelerometer and SD card device as well as makes recommendations for both enhancing the testing device and further packaging prototypes.

1.0 Introduction

As the packaging industry continues to remain an important part of modern consumer society develop, sustainability is also increasing in importance. According to the article, Why is it so hard to get rid of cardboard boxes?, "In 2017, Amazon alone shipped more than 5 billion items to homes worldwide, largely in paper envelopes and cardboard boxes. Blue Apron sends 8 million cardboard boxes every month" (Keiles, 2018). While this method is convenient and efficient in many other ways, consumers end up with excess boxes and packing material they don't know what to do with. Because the ordinary size of a delivery box is often larger than ordinary household trash cans. The used boxes are not the right size for regular trash cans, so other methods such as wedging them between the can and the wall have been devised. This is simply not adequate for buildings with twenty or more tenants (Keiles, 2018). While the boxes used in packaging create a lot of waste, the packing materials themselves used to protect the products also create a lot of waste. Some of the most common packing materials include packing peanuts, only some of which are biodegradable, but they take up unnecessary space and are not always effective. "While peanuts can conveniently alter their arrangement within the confines of

a box, simply not having *enough* peanuts can cause a product to migrate to one side of a container-resulting in a damaged piece of gear should, heaven forbid, the inevitable occur" (Fackler 2010). Another common material is bubble wrap, which uses less material than peanuts and takes up less space, but is made of plastic. According to the article, <u>Disadvantages of Bubble Wrap</u>, "Because plastic polymer film breaks down slowly, bubble wrap causes a significant environmental problem by taking up space within landfills worldwide" (Rogers). There are many options for packing material, but very few that both save space and that are environmentally friendly. This project focuses its attention on packing materials, aiming to develop prototypes of packing materials that are more sustainable by protecting the products *and* saving space.

In order to do this, the project focuses on the three components of packaging. The first is the materials used, meaning that the packing material must be biodegradable or reusable. The second is the packing structure to minimize material use as well as the size of the box. The last is the ease of use/acquisition so that customers are more likely to choose this more sustainable packing material.

In order to test the effectiveness of the packing materials, different packing categories had to be established. One type of packing is custom packing, in which the packing materials are made specifically for a certain product. For example, Apple uses their own packing methods because they know what their products can withstand without getting damaged. Another type of packing is general packing, which works for most products, whether it be heavy or light, sturdy or fragile. This is the category this project is aiming for, but within this, "good" and "bad" packaging had to be determined and defined. Tight packaging was defined as "bad" because it doesn't allow for movement within the box and therefore makes the product feel the same impact as the box itself. While Apple products have tight packaging, the company has custom packaging made specifically for the durability of their products. This wouldn't work for a regular packing material because not all items being shipped have the same durability. Loose packaging was also considered "bad" packaging because the product would move up in the package during the freefall, but then have almost a double impact because the package hits the ground and then the

product hits the packaging that it wasn't protected on the way down. "Good" packaging was considered to be packaging that was tight enough to make sure the product moved with the package on the freefall in order to avoid the double impact, but loose enough to allow break time over a larger distance. For example, bubble wrap works because the bubbles are soft and compress when you push them. When the package feels an impact, the product would slow due to the bubble wrap and therefore feel a smaller force

2.0 Methods

2.1 Impact Measurement Device

An impact measurement device based on two accelerometers measuring and calculating the net acceleration of a test package experiencing impact was developed. The software works by taking the net of the three axes of acceleration and recording a data point every XXX seconds. in order to smooth over wildly fluctuating data, a 20 data point rolling average was calculated, and it is this rolling average that is stored on an SD card for later analysis. One accelerometer attaches to the shipping box itself while the second device sits in the packing material (acting as the shipped product). The way the package versus the product moves helps determine if the packing material would actually protect the potential product. Because the package would sometimes fall on different sides during tests, a guide (see below) for the package was also made in order to obtain consistent data. The sides were tall enough to drop from a certain height without turning and wide enough to allow the package to free fall, but not hit the sides that could possibly change the data.



Figure 1: Sketch of Test Box Guide

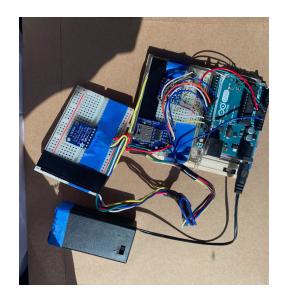


Figure 2: Accelerometers w/SD Card and Battery

2.2 Prototypes

Two packaging prototypes were developed for testing

2.2.1 Prototype #1 - Saran Wrap and Cotton Balls

For the first prototype, saran wrap was wrapped and sewn around cotton balls. Saran wrap was used in this prototype to represent bee's wrap a sustainable material with the same properties(sticks in a way that is easy to take apart, but resists itself when rubbed together). The friction between packets will ensure that the product does not shift to one side of the box while minimizing overall material. Cotton balls are also used because cotton is a biodegradable material that won't leave a trace behind once its use is over. Excess plastic from plastic bags is also an option to use instead of the cotton balls because it reuses already wasted material that would otherwise not be reused.



Figure 3: Prototype \$#1\$ - Saran Wrapped Cotton Balls + Plastic

2.2.2 Prototype #2 - Reused Plastic Rings

The second prototype consists of used plastic from items such as bottles or single-use plastic containers. Strips of the plastic are used to form a hollow ball shape that would be in the sphere naturally but would morph into other shapes when needed. This packing material takes up a little more space, however, it is sustainable in the way that it reuses materials. And while it takes up space, it is hollow, so it uses as little material as possible. With this prototype, when the package feels an impact, the force would compress the spheres a little on one side of the package and expand on the other to compensate for the force. The product would feel less of an impact than the package itself, and the spheres would return to their normal shape. Because there is space in between each ring, the individual spheres would also be able to lock together in a way, so there won't be enough movement for the product to slowly move to one side of the box.



Figure 4: Prototype #2 - Reused Plastic Rings

2.3 Sustainability Index

A set of criteria was developed that includes all of the aspects relevant to measuring the sustainability of each packing material. The Sustainability Index will be a score between 0-60 and can be used to evaluate both new packaging prototypes and existing products.

2.4 Sustainability Validation Index Chart

Production process	What machinery is needed to produce the product + what is needed to power the machine?	How much pollution is created from the production process?	Average of 1 to 5 scale throughout the column
Waste material	Volume of material wasted?	Can the material be reused?	Average of 1 to 5 scale throughout the column
Disposability of waste material	How long does it take to dispose of?	Does it need machinery? If so what is needed to power the machine?	Average of 1 to 5 scale throughout the column
Material(s) used in	Volume of material used	Can the material be reused	Average of 1 to 5

product			scale throughout the column
Disposability of product	How long does it take to dispose of?	Does it need machinery? I what is needed to power the machine?	
Amount of space the product takes up	Volume of space taken up	Better in smaller box vs. larger?	Average of 1 to 5 scale throughout the column
Reusability	How many times can you use the product before it is unusable?		Average of 1 to 5 scale throughout the column
Protectiveness	How much shaking can the object inside the packing material handle until it breaks?	Test 1 Damage on on ite packing material Test 2 Damage on on ite inside on on ite packing material	the column ge m
Weight	How much does the material weigh to protect the item?		Average of 1 to 5 scale throughout the column
Cost	How much did the materials for the product cost?	What machinery was used and how much is that?	Average of 1 to 5 scale throughout the column

Safety	Is the material toxic in any	In what ways can the packing	Average of 1 to 5
	way?	material hurt you?	scale throughout
			the column
Time	How long does the product		Average of 1 to 5
	take to put together?		scale throughout
			the column

2.5 Product Safety Testing

existing packaging materials such as bubble wrap and styrofoam were tested using the impact measurement device described in section 2.1 These existing material tests were used as a baseline for comparison. Newly developed prototypes should meet or exceed the protection ability of existing products. Additionally, tight (folded sheet) and loose (lightly crumpled paper) packaging was tested to provide additional comparison data.

As the prototypes were developed, they were tested using the two accelerometers as described in methods and were recorded in order to see what needs improving. One of the accelerometers was attached to the wall of the package box to simulate the impact of the package itself. The other accelerometer was placed in the center of the box surrounded by the test material to simulate the impact of a potential product. The test consisted of dropping the box from the same height multiple times in order to achieve consistent results. Because the package would sometimes flip when dropped, a guide as described in 2.1 was created so that the box was forced to land the same way each drop. Using this process bubble wrap and packing peanuts, two common packing materials, as well as one prototype material described in 2.2.1 were impact tested for protection validation.

3.0 Results

In the following tests, blue represents the product surrounded by the packing material while orange represents the package itself.

In order to simulate "tight" packaging, a sheet was wrapped around the accelerometer representing the product. This is because a sheet is very dense when folded together and does not allow for a lot of movement at all. "Bad" packaging type #1 (tight) showed results as follows:

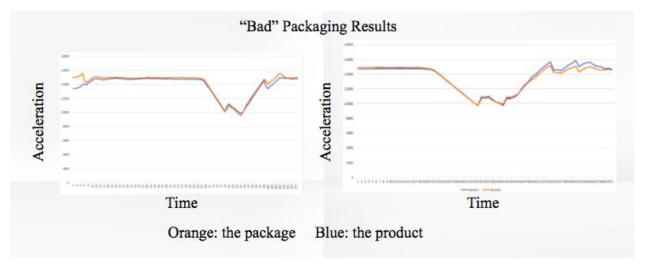


Figure 5: "Bad" Packaging Results Data Graph - Type 1

There was very little difference in the acceleration of the product (blue) versus the package (orange). This is because there was no room for the product to move. Because there is little to no room for the product to move independently of the package, the two experience the same accelerations and therefore the same impact forces as well.

In order to simulate "loose" packaging, very little paper was used in the box as packing material. This is because loosely crumpled paper allows for a lot of movement. "Bad" packaging type #2 (loose) showed results as follows:



Figure 6: "Bad" Packaging Results Data Graph - Type 2

Again, the product (in blue) showed the same acceleration as the package (in orange). This is because there was nothing to slow down the product as it fell and hit the ground, so it also just felt the same impact as the package. In the graph shown above, blue is higher than orange because of a small coding issue. Rather than just showing acceleration, the code adds onto it over time, leading them to be higher than each other with little movements unrelated to the impact itself.

"Good" Packaging Results

Time

Time

Orange: the package

Blue: the product

"Good" packaging, using packing peanuts, showed results as follows:

Figure 7: "Good" Packaging Results Data Graph

The product (in blue) showed more acceleration than the package (in orange) because as the product crashes with the package, the packing peanuts allow the product to continue acceleration, however, it is a slower acceleration so the force at the bottom isn't as harsh. With the package, the ground doesn't allow for that type of crash, so the force on the package is much larger, but shorter. The force on the product spreads out, meaning that it feels the same force overall, but since the duration of the impact is longer, it feels less of an impact at any given second.

When prototype #1, using the cotton balls, was tested, the data showed similarly, but inconsistent data correlating to the "good" type of packaging. Some of the time, the package itself accelerated more than the product; however, sometimes, they accelerated at the same time.

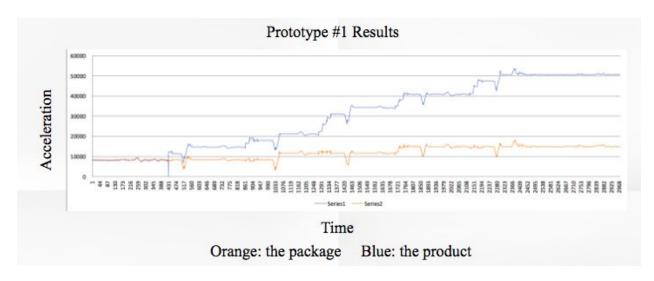


Figure 8: Prototype #1 Results Data Graph

In this photo, there were actually five drops, but because of the coding error as described before, the data was difficult to dissect. Like the packing peanuts, the cotton balls allow for the product to slow down immediately after the impact, so it accelerates more but has less of an impact, which is what we are going for. The blue is higher than the orange because each time blue accelerates more, it rises. Here blue accelerated more than orange every impact.

4.0 Discussion/Future Work

The results for prototype #1 were positive in terms of protectiveness, however, the data was a little inconsistent in the way that it didn't always test positive. Also, in order for the products to be cost-effective, they would have to be produced on a larger scale rather than individually hand made. Another limitation includes collecting plastic bags and bottles in order to make the packing material. They would have to be sanitized, and using a lot of water to do so would not be very sustainable. Since prototype #1 can be easily punctured, the packing material would not work with any items with any sharp edges. And prototype #2 would not work with any items that could easily be scratched because the sharp plastic edges would scratch the item being shipped.

In the future, there should be a better accelerometer that is more consistent and that is easier to use and that shows the data in a clearer and easier way. The process of changing the code for a new file name, moving the SD card from the Arduino to the laptop, and plugging in

and taking out the cord each test was a hassle. The way the code transferred into excel was also not very easy, as you had to convert the data into a chart and then find the sections in which the impacts were, and then find it hidden in the excel document each time you went back because they were so small compared to all the data given.

The next engineer for the project would also have to fix the code error of acceleration just being added in addition to having a better understanding of the relationship between acceleration data and the impact of the package. They would also have to develop a numerical measurement of impact from the data for easier comparison. Once these, what should be, small changes are made, more packaging material designs prototypes should be made. Once refined, maybe they actually are shipped out and tested that way as well. For this, the code may have to be altered so that it only records big impacts so that there aren't hours and hours of data to go through and analyze. In this project, the chart shown in 2.4 Sustainability Validation Index Chart wasn't actually used, but in the future, it should definitely be used to determine which packaging prototypes are the most sustainable, yet also fulfill the protectiveness validation.

5.0 Conclusion

The goal of this project was to design and prototype more sustainable options for packing materials. First, accelerometers were built and programmed to measure the force it feels. Then using an SD card, the data from the accelerometers was put into excel and graphed. A few packing prototypes were also made and tested. Using the data results, they were analyzed to understand what was happening.

6.0 References

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Mr. Buxman and Bruce Waggoner helped throughout the process of the project Janna and Alice also provided advice throughout the completion of the project.

7.0 Appendices

- Original Project Proposal
- Project Journal
- Protection Validation Commented Code
- Accelerometer Testing User Manual
- Hardware Wiring Diagram