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A Study in the Use of Elastic Materials in Expandable Containment Units

A RESEARCH WEEK STUDY

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Abstract

The rigidity of materials in conjunction with the aspect of elasticity has been a concern of modern technologies and construction in recent centuries because of the advantages that expandable storage would bring to the fields of containment units with respect to population growth and space exploration. The world population is currently growing at an exponential rate, and as our population grows, the more important it will become to have containment units that can both contain large volumes of material as well as minuscule amounts of material without wasting space. In order accomplish this, we will need a new type of storage container that utilizes the inherent strengths of both flexibility and rigidity to find a unique balance between the two. The purpose of this study is not to necessarily find the final answer to the question of expandable storage, but to narrow the range of questions that later research will use to finally answer the question, “How will we do it?” In order to research the utility of elastic material in creating storage devices in the same manner as has have described, this study would create an expandable backpack as a scaled-down case study. The backpack utilizes grooved panels made of lightweight, rigid material such as PVC-plastic in conjunction with elastic cloth, made of a mix of nylon and spandex, to create a container that will stand rigid on its own, but also expand in horizontal directions so that it can hold objects larger than its original volume. By creating male and female connectors in the individual panels, the container will be able to stand rigid, but also expand using elastic cloth sandwiched between the halves of each panel. The front and back of the container will be made of two panels, but the sides will be made up of 4 panels, so that expansion is more likely to occur in those directions, as well as lessen the stress on the fabric. In order to create the container, the team sampled multiple ratios of nylon-to-spandex, as well as tested the rigidity of different woods and plastics. Upon deciding on a material, PVC, a prototype was built and tested. The testing process involved filling the container to with varying amounts of weight, such as textbooks and laptops, and having a test subject walk around carrying the objects for varying amounts of time. The study also tested the amount of volume the backpack is able to expand, aiming for between five and ten percent increased volume. While the purpose of this study is not to solve the problem of expandable storage definitively, the concept of elastic cloth between interlocking panels has a high likelihood of being a step in the right direction.

Keywords: Expandable, Containment, Overpopulation, Elasti

Introduction

As the world's population grows, it in turn runs out of space. Over the past 10 years, the population has grown from 6.6 billion people up to 7.5 billion people. This growth has shown no signs of slowing down, and this will bring many problems with it in the years to come. One such issue that is very rarely discussed is the issue of storage. As it stands now in most first world countries, most families require a certain amount of storage space in their living quarters not just for the possessions that they use on a regular basis, they also store a lot of items that are either seasonal, such as Christmas decorations, or of great sentimental value, such as a grandparent's military chest. As our population increases over the next century and living quarters become a premium, so will storage space. As a result of this, it will be important that we have access to storage containers that can be useful in both small living spaces, and in large living spaces. There are many paths that could be taken to achieve this goal, interlocking panels, segmented chambers, or even elastic building materials. This study's purpose is to explore one such option so that future research teams can build upon it and eventually find a solution. The option that this team has chosen is to explore the use of elastic materials.

Problem Definition

In order to combat the eventual side-effects of overpopulation, an expandable container that can rest at a small volume and can expand to hold a larger volume while still retaining its structural needs to be designed. As such, the Expandable Containing and Holding Unit, or E.C.H.U. as it will now be referred to for the sake of readability, is a containment unit that has a state of equilibrium, but can reach states of higher capacities and larger internal volumes when such demands are in place. Immediately identifiable applications would be mailing packages, shipping containers, long-term storage units, and space traversing storage systems.

Design Requirements

ECHU is required to be a rigid, stand-alone structure when under no duress, but maintain structural integrity when at the limitations of its expandability. It also must be highly water-resistant to better protect the contents. ECHU will have one partition of access via a sealable lid. For immediate testing, ECHU will be a Liberty University Engineering student's backpack for two days. As such, ECHU must also have straps that are adjustable in length to better accommodate the comfort of the user. A backpack design was settled upon, versus a shipping container, due to ease in transport and budget limitations.

Feasibility

For each phase of the Project, certain deadlines had to be met. For the benefit of all members on the ECHU Team, soft deadlines were set up for each individual member so as to complete each hard deadline within an appropriate time constraint. Deadlines for each member were set a couple of days before the hard deadlines set by Liberty University to allow for any unforeseen delays or complications, as well for formatting and editing when all pieces were brought together. Each member then took his turn to peer review and edit the conglomerate of work in an attempt to find any mistakes in grammar or formatting that the other members may have missed. Below is a list of due dates associated with the rules and guidelines of conducting a Research Project for the Liberty University Research Week.

- February 8 - Presentation Style
    - The team had met on February 8th and unanimously decided for publicly presenting the research via PowerPoint.

- February 13 - Sponsor
  - ECHU team contacted and met Professor Ziebart early that morning
- February 18 - Abstract
  - Written by all team members
- March 1 - Research Submission Deadline
  - ECHU team submitted the completed works of having a faculty sponsor, choosing a category, choosing a presentation style, writing the abstract, and writing the biblical worldview on the project
- March 15 - Submission of PowerPoint slides and Design Process
  - Various sections of either project were divided up among the team members on the 11th of March
- March 25 - All research and submissions due
  - Complete straps and closing mechanism
  - Calculate volume at rest
  - Fill backpack with average amount of student gear
  - Calculate expanded volume
  - Conduct stress tests of 1-2 days
  - Calculate expanded volume again
  - Calculate volume at rest again

Conceptualization

Mrs. Carolyn Ziebart, professor of Engineering at Liberty University, agreed to be the project's faculty mentor, and directed the team to talk to her husband, Mr. Ziebart. He has been a Mechanical Engineer for over 25 years and met with the team to talk through the project. In explaining the problem and desired solution to him, Mr. Ziebart's initial idea was to make a kind of balloon of tough material that was encased in a wooden or metal box frame. This idea would not be difficult to attain and effect, however, stacking multiple units on top of and alongside many others would be problematic as the enjoining sides are not flat. The team's idea was to make a box that allowed its sides to change position relative to the box's center, and maintain contact with all other sides. In this way, all enjoining sides would be flat and stackability would be more attainable. Mr. Ziebart's primary concern with the team's desired solution was what he called the "Sitting Man Problem." When not stretched and its primary state of equilibrium, could the unit survive the weight of a man sitting atop the unit, much in the same way that an igloo is tested for its integrity. An additional concern of Mr. Ziebart was that when the sides of the unit expanded, some amount of vertical dimension would be displaced, and the unit would be shorter in its maximum state compared to its primary state. For the time constraints associated with Research Week, the team will not be able to implement potential solutions or alternatives in relation to the scenarios proposed by Mr. Ziebart.

Design

The ECHU Project Team Leader, Andrew Eisenman, had sketches of the desired product well in advance of making a formal research team. Initially, his sketches had noted that expandable containment unit would be made of wood and spandex. After discussing with his Freshman Team Members, Joby Anthony III and David Satagaj, the expandable containment unit was decided on being comprised of a thin, stiff polyvinyl chloride (PVC) and a material that was a mix of spandex and nylon. The spandex-nylon would be attached to the PVC via spray-on contact cement. Of the six sides of backpack ECHU, only four will change their dimensions. The base and lid of the backpack will remain one size so as to give the backpack an anchor point for the other four sides. The four sides would be comprised of various, trice-layered, interlocking sections of the PVC. Using the contact cement, the spandex-nylon is placed between any and all sections of present PVC sections, save the lid to allow its opening and closing abilities to remain unhindered. The four sides will not remain perfectly flat as initially desired, and will be slightly rounded in effect because of pressure that the contents will apply to ECHU. The volume of backpack ECHU can be calculated by the formula in Appendix A. Cost of all materials was priced to be $150, and enough material was purchased to make two backpacks. Given the time constraints and demands placed by Liberty University’s Research Week, one backpack was deemed sufficient for the project’s purposes.

Manufacturing

With the aid of the Liberty University Machine Shop contained within the School of Engineering and Computer Sciences department, ECHU was assembled. The PVC was cut using the Universal Laser System PLS.45. The roll of spandex-nylon was cut using basic scissors with fabric tracing paper as a guide to make sure all pieces were of equivalent sizes and dimensions according to the section of ECHU that the pieces corresponded. Once cut, actual assembly was done on a covered table to prevent accidental adhesion of components to the table surface. Contact cement would be sprayed onto the various components that were then held together with a series of clamps and vices to make certain that the pieces would not move while the cement cured. On the whole, assembly of ECHU N. 01 took approximately 3 days of work. Mass production would be possible given that a Computer Numerical Control (CNC) machine could cut out the sections of PVC, and an assembly line could be set up with robots or personnel at the ready to dispense contact cement, put the pieces together, and apply clamps to the various pieces.

Procedure of Experiment

In order to determine whether or not ECHU would be a successful solution to the established problem, an experiment was designed to test ECHU. One of the team members, Joby Anthony III, wore the pack for 48 hours as his normal school bag, carrying an average amount of student’s materials to test if the backpack would handle carrying a small volume of items without structural decay. After doing so, it was decided that the maximum volume that the backpack should be calculated. In order to accomplish this, various jackets and assorted clothing items were stuffed into the ECHU so that it expanded to its full volume. This method was chosen due to the fact that these items, being pliable solids that had no inherent rigid structure, would fill the volume more completely than say, a collection of small boxes, and would lead to a more complete approximation. In order to calculate this, it was assumed (in formula 1, Appendix A), that the path of the expanding segments were parabolic in nature. This was done to ease the difficulty of the calculations, so while the approximation is close, it remains just that, an approximation.

It was decided beforehand that if the backpack reached even 5-10% expansion, the experiment would be determined a success, as this would be more expansion than a simple box and would indicate that there is potential within the idea of using elastic materials, but another angle might be needed to better capitalize on it.

Results

During the initial test itself, the weight of the objects did not stretch the elastic cloth over the two days, so initial indications are that it is able to operate fully functionally as a container when not holding enough objects to force the pack to expand.

With regards to the volume of the of the backpack, it’s volume at rest was found to be .87 cubic feet, but when it expanded, it had a volume of 1.72 cubic feet. This is just short of doubling the volume, rendering the experiment a success. But, not all of the results were positive. Shortly after reaching maximum expansion, the layered panels of the backpack began to separate due to the adhesive not being strong enough.

Conclusion

In conclusion, the experiment, on the whole, was a success. The backpack showed that it was able to reach a maximum expansion of nearly double its original volume. The purpose of the experiment was to prove that it was possible to create a box that used elastic materials to expand, while still retaining the characteristics of a solid container, and the study proved that. The box held the key characteristics of its shape, rigidity and the ability to balance and stand up straight while still protecting the objects from basic harm, while also expanding to almost double its volume, Going forward into the next stages of research regarding this specific project, the next questions that need to be addressed are as follows:

1. A stronger adhesion method needs to be found that will be able to sustainably hold the containers together.
2. A method of waterproofing the container needs to be found if the methods described in this study are to ever be applied to larger container. This included filling the gaps that form as the fabric reshapes its surface area when expanding.
3. Once these first two questions are answered, a method of mass production for products made through this method needs to be devised for this research to have any viable impact. A device cannot be practical and helpful if it cannot be produced. .

Overall, the experiment was extremely successful and is a good, if very small, step towards solving a lesser-talked about issue when it comes to overpopulation. If the three questions laid out above are solved in an adequate manner, then elastic materials will be extremely viable in the use of expandable containment units.

Appendix A

Formula 1: Volume

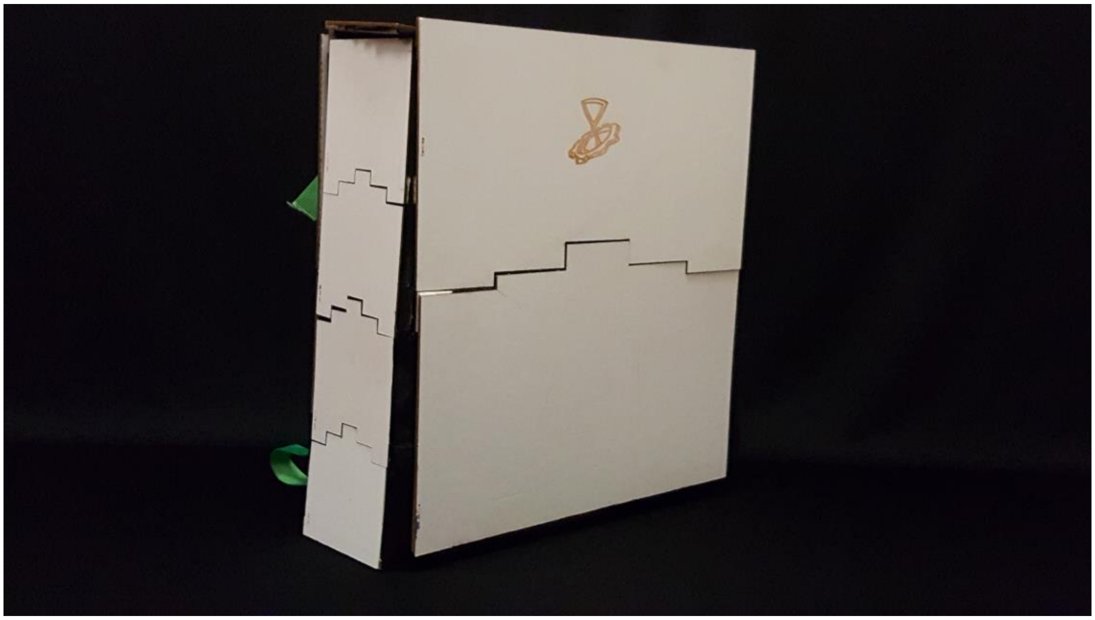
- $V_T = V_O + y_f z_f[(y_f^2/96\Delta x) + \Delta x] + x_f y_f[(y_f^2/96\Delta x) + \Delta x]$
  - V_T = Total Volume
  - y_f = y dimension when ECHU viewed from front
  - x_f = x dimension when ECHU viewed from front
  - z_f = z dimension when ECHU viewed from front
  - x_E = x dimension of side paneling when ECHU in expanded state
  - z_E = z dimension of side paneling when ECHU in expanded state

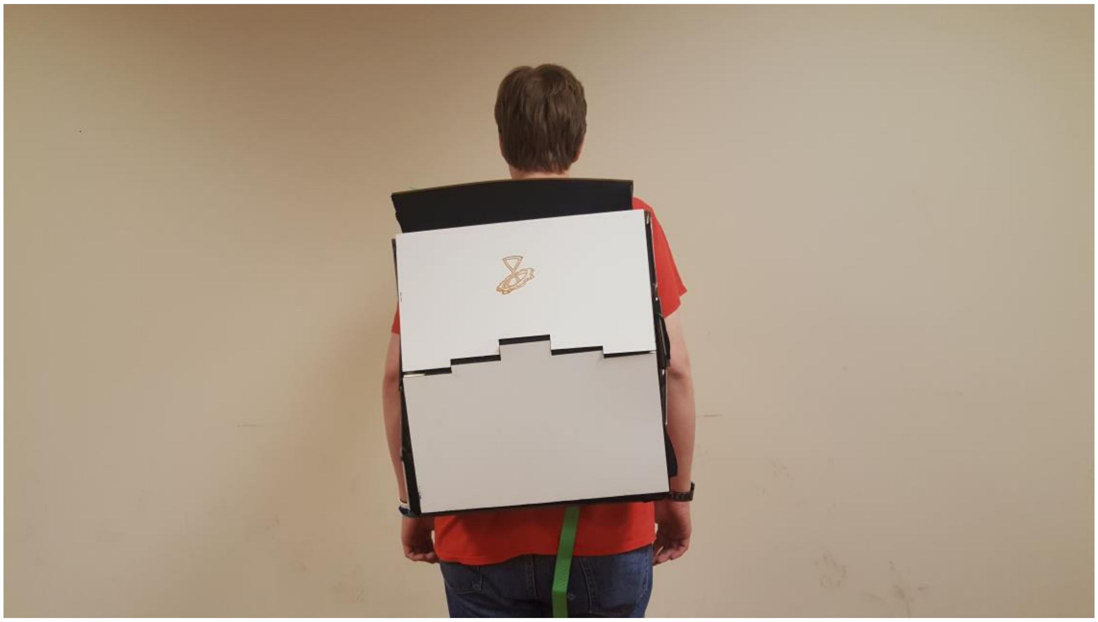
Formula 2: Weight Limit

- $M = \sqrt{[(388*F^2/g^2) - 2m^2]}$
  - F is the force is takes to expand the spring, which is data that you had.
  - g is gravity
  - m is the mass of the backpack.
  - This formula was originally used to calculate the weight limit that the backpack could hold. This was not included in the procedures because it does not take into account the strength and durability of the adhesive, but we are including it here for the sake of anyone who might replicate the project in the future.

Appendix B

- The purpose of this Appendix is to visually demonstrate through pictures what he finished construction of the project looked like, and how it expanded.



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