SUITE CASE

Team 8 (Couch Town)
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Abstract:

Many college students leave their homes and move across cities, states, and even countries to dorms and apartments that are closer to their campus. Unfortunately, having to move at least once every year to two years can be stressful. There is the stress to have to decide if a piece of furniture should be left behind or sold because it is too heavy to move in and out of the apartment, there is the stress to have to decide if a piece of furniture is worth paying for given the time period of college, and there is the stress to have to decide how to move a piece of furniture from one place to another.

Our team has each experienced the stress of moving, which has led us to come up with our product, Suite Case, a lightweight collapsible couch. Our couch is ideal for college students because it is built to be comfortable and durable, yet able to collapse into a smaller piece of furniture for transport. Our goal when coming up with this product is to create a piece of furniture that can help make a place feel like a home, while being able to tackle one of the main moving questions, "how am I going to move this couch?". The primary design criteria were then enforced while collecting survey data, (1) compactness for transport/storage, (2) lightweight for moving, and (3) aesthetically pleasing. Each of these feeds into the core objective, a couch that is easy to reuse and hard to abandon.

Ideations and Iterations:

During the early stages of the Suite Case, we considered creating an inflatable couch that can be vacuum sealed for easier storage and transportation. One of the main issues with this version of our product is the fear that our couch may deflate overtime, causing a short term use instead of long term. There would be the problem of having to re-inflate the couch every 3-4 months which can become inconvenient over a 4 year term. We pivoted from this idea and instead considered filling our couch with expanded polystyrene beans, but similarly, we did not want to risk the fear of deflation overtime. Eventually, we researched the mechanisms of camping furniture because of their ability to collapse and expand. During this period, we wanted to implement the same folding mechanism for our couch while using fabric all around to hold cushions for the seats and backrest. With further research, we decided that

this product would be too identical to camping furniture and would not provide the aesthetics and comfort of at home furniture. To sway away from the looks of camping furniture, we decided to research different designs, which led us to our M shape fold. This version of our couch was going to be created by combining 6 panels, 2 for the backrest, 2 for the seats, and 2 for the armrest with 90 degree foldable hinges in between each panel. The hinges allow the back rest to fold down and the center joint enables the entire couch to fold into a M shape for storage and transportation. This version of our couch was closer to becoming our ideal product but there were still some concerns, such as, the lack of support towards the center of the couch, the lack of stability all around, and the fear of the couch being naturally inclined to bend down in the center. From this version, we considered creating a W shape fold instead and include legs in the center for support. Unfortunately, we did not have the time or resources to build this version of the couch. Which led us to our final product, the A shape fold. The A shape fold ultimately became our final decision because the materials were readily available to us, this cut down the cost of materials and time. This fold would have the base of the couch fold upwards in half and have the supports concealed in the folded base.

Once we had agreed on the basic A shape to our final product the next step involved establishing design constraints that would enable the team to deliver a fully realized prototype. Since the scale of our project was sofa sized, cost became a core motivator in terms of the design process. Next, we selected compressibility as the other focus of the project, setting the aesthetic and weight design objectives to be figured out in mach 2 of the Suite Case. The primary tools used at this phase were thus aptly abbreviated as DFCs, Design for Cost/Compressibility. A core choice which emerged from this was the use of plywood for a majority of the sofa's body, as the team had an abundance of free plywood on hand, reducing the prototype cost by around $200. With this price cut came one critical trade off, the lightweight design objective could not be satisfied. With the base of the A shape fold made with plywood, and the focus set on compressibility, we got to work refining our designs in the development stage.

M Shape Folding Couch:

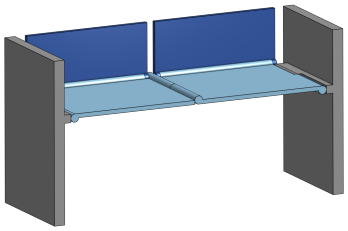


Figure 1a

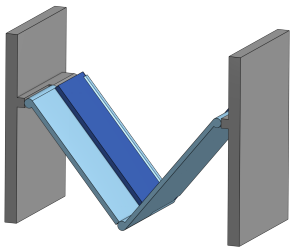


Figure 1b

W Shape Folding Couch:

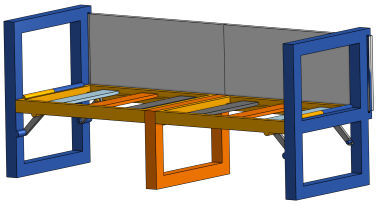


Figure 2a

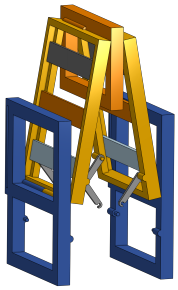


Figure 2b

A Shape Folding Couch:

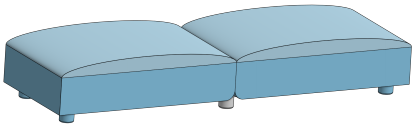


Figure 3a

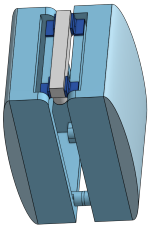
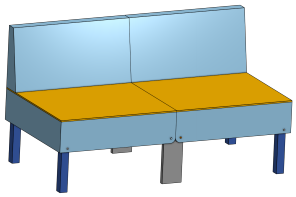


Figure 3b

Figure 1a, 2a, 3a: fold out state of the M, W, and A shape couch, respectively.
Figure 1b, 2b, 3b: fold up state of the M, W, and A shape couch, respectively.

Developing Stage:

Although the decision between M, W and A frame had already been made, the early stages of our final design included many changes. One of the major changes surrounded the design of the backrest. Infact, deliberations over the backrest were running a week past the desired date for design completion. In order to meet our delivery deadline it became necessary to agree on a simple base design before we had agreed on the backrest. Early backrest concepts simply imagine a hollow wedge design that folds onto the base. This design while simple would increase the weight of the prototype substantially and mean that the cushions would need to be removed every time you folded the Suite Case (see Figures 4a & b).



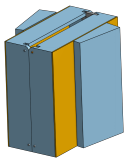


Figure 4: (a) early CAD of open sofa, (b) early CAD of closed sofa, & (c) final design side view.

After much deliberation we found that the more interesting design would involve having the backrest fold out, allowing the final product to double as a futon (See Figure 4c). This too came with the task of sourcing a folding bracket that could be modified to allow for a resting angle of 75°.

Another key point of conflict in this design was the center legs, unlike the average couch our product utilizes six legs instead of four. By including these legs we effectively increased the stability of our entire base and sacrificed space and ease of foldability. Due to the framework of the class and limited time our prototype is on the smaller side of the spectrum, meaning that in order to achieve the desired seat height our legs had to be rather long relative to the rest of the couch. In early CAD models and rough hand sketches we ran into the problem of the outer legs interfering with the center legs when folding meaning the portability and storability were at risk. To combat this issue we had to increase the depth of the base frame to 6” so that the outer legs would meet up with but not conflict with the center legs. This

also meant that when sourcing folding brackets for the outer legs we had to find one that when closed would not exceed 1” in thickness (see Figure 5b).

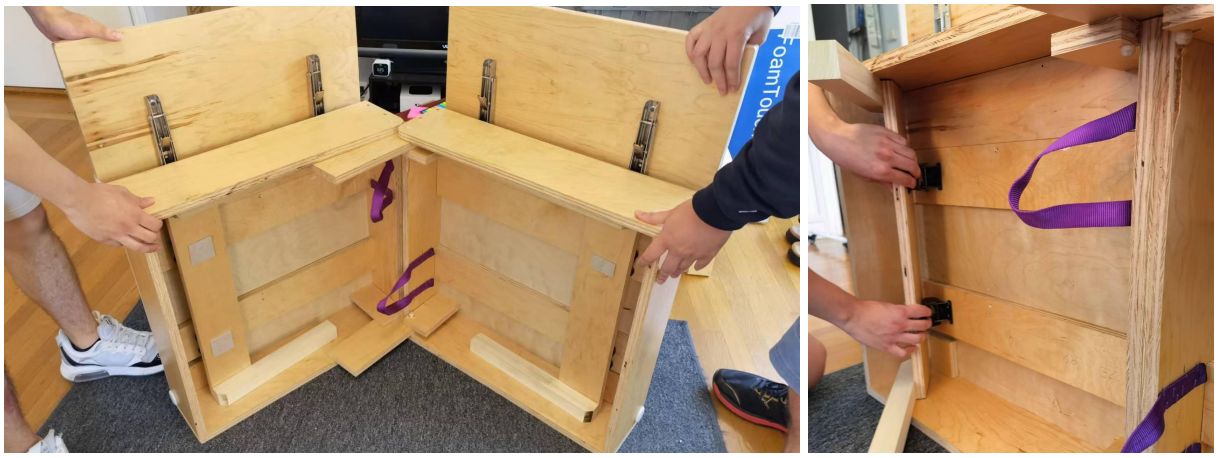


Figure 5: (a) photo showing the leg overlap & (b) photo showing outer leg hinges.

When the legs are fully closed they are locked in that position, meaning that when the couch is unfolded there is no way the outer legs will interfere with the center joint or legs (see Figure 5a). At this point in development we began recognising that if we made the couch longer we would have been able to reduce the relative thickness of the folded Suite Case, which is an easy improvement for the next generation.

Before the final assembly of the project could commence we had to ensure that the couch was robust enough to survive a core failure mode which is intrinsic to the product concept. The introduction of two midspan linkages has been a source for concern in relation to having a functional prototype. To alleviate this concern an FEA was performed on each of the center linkages without a built in leg, to evaluate the worst case. Before the simulation was run, we conducted a FBD to derive a relationship between the weight of the sitters and the tension transferred to the middle linkage at the bearing. The expression $T = (W_1 + W_2 + W_{sofa})l/(8h)$, with l representing the length of each half of the couch and h representing the height of the upper edge relative to the bearing. From here the simulation, for two 250 lb sitters and a 40 lb couch, showed that the maximum stress in the linkage was around 1494 PSI, which was well below the ultimate tensile stress of plywood, around 8140 PSI (see Figure 6).

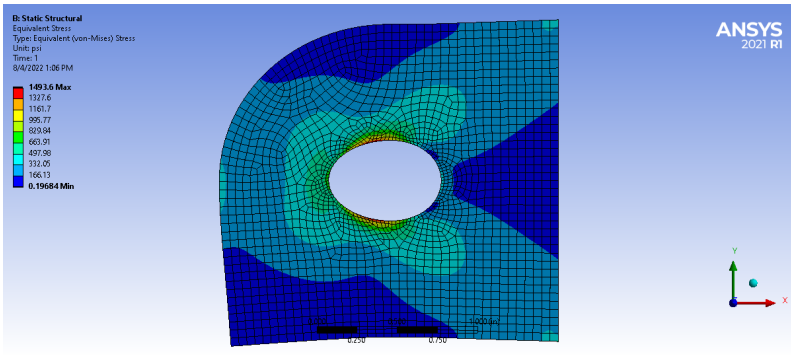


Figure 6: Equivalent stress FEA for middle linkage (with no embedded leg).

This meant that it may be possible for the prototype to have no middle legs, but it also revealed that if you increase the length and shortened the height, as we proposed in this section, you will be increasing the tension at each bearing and thus increase the likelihood of failure. For this reason we decided on keeping the middle legs for the additional robustness they provide along with the opinion that a mach 2 of this concept will likely require them.

Final product:

After a semester of continuous improvement, we finally realized our couch. When the couch is not folded, it is the size of a two-person couch. And after folding up, it is the size of a suitcase.

Figure 7: (a) Suite Case in “couch mode” & (b) Suite Case in “case mode”.

When we want to fold it, our first step is to press the spring structure of the hinge on the back of the backrest to flatten the backrest and secure it with velcro (see Figure 8a). Then press the locking hinge joint for the outer legs to pull the four legs in (see Figure 8b).

Figure 8: (a) step one, (b) step two, & (c) step three.

The third step is to fold the sofa in half to make a box the size of a suitcase (see Figure 8c). There is no need to remove cushions during actual use. We take the cushions off the sofa for the demonstration.

According to our simulation, installing two legs in the middle of the sofa can significantly improve the stability. So our sofa has six legs, two in the middle and four on each side. The two legs on both sides are fixed together to ensure stability, and we have stiffeners (visible in Figure 8b) to better transfer the weight to the legs without making the sofa sag in the middle.

There are three kinds of joints in our sofa, one is the backrest joint, another is the leg's joint, and the final one is the center linkage (see Figure 9a, b, & c respectively). It requires a lot of technology and time to make joints, so considering the stability and cost, we decided to purchase two joints online. However, the backrest joint is not completely suitable. After we received the backrest joint, we realized that it only has angles of 90° and 0°, which are not suitable for the back of the sofa. Because of this, we cut off 1.03 inch of the middle support linkage so that it creates 75° and 0° two angles to fit our sofa.

Figure 9: (a) Backrest joint, (b) Leg joint, & (c) Center linkage.

After weighing aesthetics, comfort, volume, and time constraints, we came up with our final prototype of the sofa. Similar to a regular sofa, our sofa brings stability and comfortability to users. In the meanwhile, it can also be folded to the size of a suitcase so it can be carried around. Since this is just our first prototype, there are still things that we looked to improve on. In the second generation, we want to integrate the back frame fold so it is flush. We also look to integrate slides so the back frame can be slid in. In addition, we want to optimize the appearance so it is more aesthetically pleasing. Starting by covering the body with soft fabric, we plan to use thicker sponges and sofa springs to make it more comfortable and reminiscent of a sofa that people can find on the market.

no.	**Dimensions**	**Description**
4	¾”x6”x2’	Base Front & Back (w/ 1” radius fillet on one corner)
2	¾”x6”x22-½”	Base outer Sides
2	¾”x5”x22-½”	Base Inner Sides (w/ ¾”x¾”x1” cut from two corners)
8	¾”x4”x22-½”	Stiffeners
2	¾”x4”x10”	Center Linkages (w/ 1” radius fillets on two corner)
2	¾”x14”x2’	Back Rest
2	¾”x3-¼”x6”	Front Center Linkage Alignment Plates

2	¾”x3-¼”x5-¼”	Back Center Linkage Alignment Plates
2	¾”x3-¼”x3-¼”	Normal Contact spacer
4	1-½”x1-½”x13-½”	Legs
2	¼”x2’x2’	Shear Skin

Table 1: List of Woodcuts

Summary and Reflection:

Throughout this design process we accomplished many things, we successfully created a team, developed a set of rules to follow, assigned specific roles to each participant, and worked together to finalize a complete prototype. In each stage of the process we learned a lot, each individual brought their own perspective to the table and we were able to talk and work through any speed bumps, misunderstandings and design problems along the way. In the beginning of the class we set out to solve one problem: college students and those people that move often have a very hard time moving large bulky sofas from one house to another. To solve this problem we came up with a sofa concept that was portable, easily collapsible, durable and aesthetically pleasing. In the short time we had to develop a prototype we checked many of these boxes but also fell short on a few.

Durability was one of, if not the most, important need this product had to satisfy, it needed to be able to take the wear and tear of college life and the constant folding and unfolding necessary for several moves. Although we only just completed this prototype and cannot speak on the longevity of the product, it can easily hold the weight of an above average sized person, and can comfortably fit and hold two people weighing over 400 pounds. As far as holding up during transportation and being able to fold and unfold multiple times our prototype has been successfully transported 30 miles by car and has not shown any signs of fatigue in the dozens of times we have put it together and taken it apart.

After ensuring our product was durable enough for our intended customers we needed to make sure they could easily operate the folding mechanisms allowing them to set up and collapse the sofa with no problems. In our trials two people were able to fully expand the sofa in less than two minutes and one

person was able to do it in roughly the same amount of time, however, the bulkiness of our prototype made it hard for a single person to comfortably handle.

Not only did the bulkiness of our prototype add some hiccups to the ease of collapsibility for one person, it also made it less practical for one person to transport. We intended for this product to be extremely portable so that an individual could easily take their sofa with them when moving from one home to another, however, due to the structure of the class and limited time for construction our prototype was heavier than anticipated. Although it is completely possible for one person to transport the prototype it is far easier for two people to handle and maneuver. In this aspect we fell slightly short of our anticipated target but can easily fix this problem with different base materials and more time to test our models.

We may have only come up slightly short in our goal to make a very portable sofa, but one area that can be much improved is the aesthetic of our product. The current image of our product is clearly that of a prototype, screws are visible, the framing wood is still showing and all of the rear hinges are still exposed. Although the current prototype would not be a complete eyesore in a college apartment it is nowhere close to the standards of an average traveling adult. Similar to the solution to our problem regarding portability, the solution to the aesthetic of our product is time. With more time we would be able to upholster the entire frame, hide the rear hinges and paint or stain any remaining visible wood pieces.

With all this said there is clearly room for version 2 of our product. We will do research on different materials for our frame, such as the composite material used by brands such as IKEA, look into adding certain aspects such as armerests, perform simulations to ensure that lengthening our sofa will not sacrifice its structural integrity, and research ways to upholster our entire sofa. These improvements will allow our product to strengthen those areas in which it fell short and will ultimately satisfy above and beyond every goal we set out to accomplish.