ENGR 0097-06 Undergraduate Research in Engineering: Origami Structures and Mechanisms

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Abstract

Our independent research for the semester looked at applying the principles of origami structures and mechanisms design to creating a self deploying glider. This investigation is a continuation of a summer research project done by Olin students in the summer of 2017. This report goes over the project's progress until now, and explains why we made certain shifts from the original proposed design.[1]

Design and Fabrication

Most of the work we did over the course of the semester was determining whether 3D printing was the best course of action for fabrication, and what other options we could explore for future work. Our goals were to make the glider the lighter, more compact, and motorized. While we were not able to achieve the final goal, the first two were successfully met.

We started with the glider handed down to us, and decided it was best to make the glider lighter by completely pivoting in terms of fabrication. The previous team hand been using fused deposition modeling Maker Bot Replicator 2Xs to create their wings and main frame. This however, is very inefficient due to the amount of fabrication time needed to print the entire plane, as well as printing 2D shapes can seem counter productive other techniques such as vinyl cutting and laser cutting are available.

The entire fabrication process would require three separate runs since the two wings and platform were so large, they would not fit onto the same build platform. the previous team reported having to use other commercial software and filaments besides the one provided by Maker Bot to refine the printing process. The team looked at utilizing a thermoplastic filament named Ninjaflex sold by Ninjatek that provided superior flexibility. While we believed the wing design for the origami glider was good, the fabrication and material process needed to be changed to be more flexible, lighter, quicker and cheaper to produce.

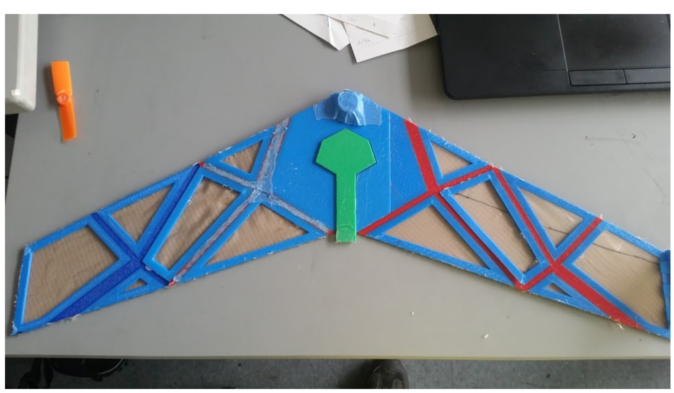

Figure 1: This is the 3D printed glider we started with a the beginning of the semester.

Having done work in origami engineering before, we decided to use lighter, more readily available materials like paper and plastic sheets to for the wings, but we believed using 3d printing might be useful in terms of creating structure for wings that had been folded over and over again. Using standard Acrylonitrile Butadiene Styrene or ABS thermoplastic filament, we created small ribs with a slight curvature to keep the wings and that curvature. We had a simple version with only ABS filament, and one with Ninjaflex at its core to provide more flexibility if the ABS only ribs were too stiff. Figure two shows an example rib with both Ninjaflex in red and ABS in yellow.

Figure 2: 3D printed ribs using Ninjaflex and ABS thermoplastic filaments to provide structure for wings.

Moving onto the actual creation of the wings. We decided on keeping the same wing design from the first summer's research team, but experiment the wing materials with paper as an initial start. Paper, as is used in traditional origami and kirigami, creases well and does not wrinkle easily, which is key for creating smooth wing surfaces. Based on previous research done at the University of Pennsylvania and MIT, we used perforated cuts to create our fold lines by using traditional 2D digital prototyping techniques like vinyl cutting and laser cutting. Experiment on the right size of perforated lines to ensure a reliable fold line that would snap off, we cut a variety of lines, changing the cut size and spaces between cuts in the line. After performing a few fold tests, we determined 1/64 inch holes with 3/32 inch spacing as a viable option. Figure 3 shows the different cuts we did, and figure 4 shows out new paper wing design.

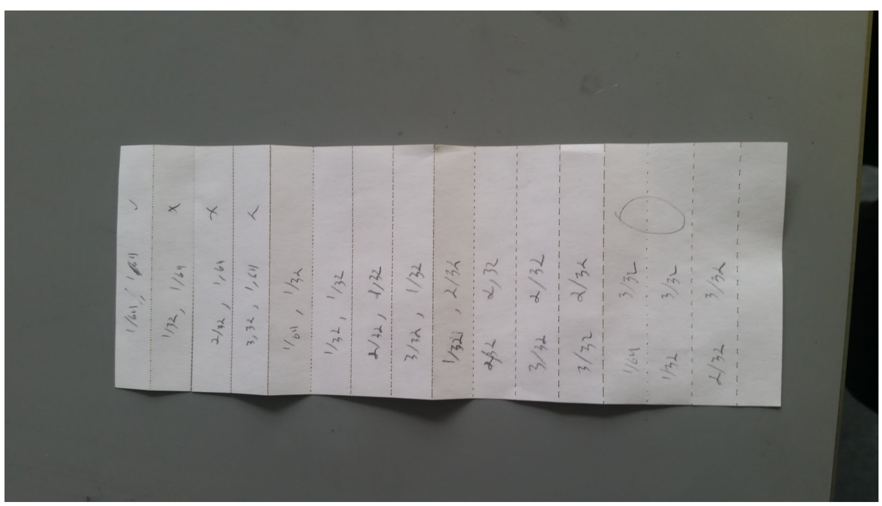

Figure 3: Laser cut line test to determine perforated cut for wing. First number is the length of the cut, the second number is the spacing between each cut.

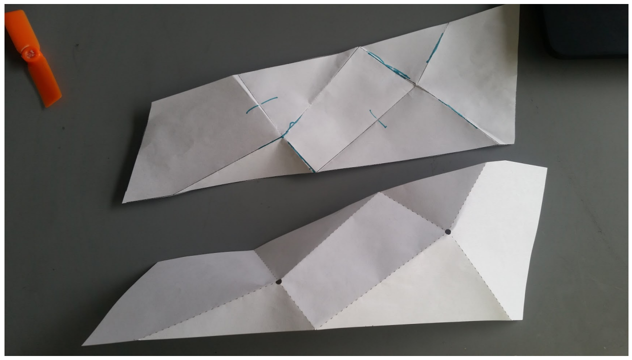

Figure 4: Paper wing design with perforated cut of 1/64 inch holes with 3/32 inch spacing.

After we created the ribs and wings, we tried attaching them using glue and tape. The ribs were placed in such a way that they would not go over the perforated fold lines. An example can seen in figure 5. Unfortunately this idea did not work as well as we hoped. Attaching the ribs to the paper proved more difficult than expected, but printing them on top of the paper instead of the platform seemed to fix the problem. The issue with this is sometimes printers can tear the paper by accident or damage it as the extruder is just starting to print the first layers. The second issue comes in the actual intended purpose of the ribs. They were not stiff enough to keep the paper at the desired curvature. We thought thick blue painter's tape would fix this issue, but had little success, and actually restricted the folding motion, making it more difficult to fold.

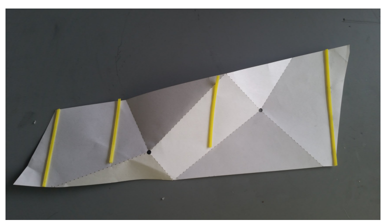

Figure 5: Wing with ribs attached. The ribs are placed so they don't interfere with folding and compacting the glider.

Figure 6: Wings with tape placed on both sides in attempt to provide structure to wing, preventing from unfolding easily.

That being said, we found a decent way to support the constant folding and unfolding of the wings. Using 0.08 diameter inch spring wire and two pieces of tape on each side, we placed the spring wire at a 10 to 20 degree angle from the perforated cut and taped it down. We did the same on the other side, basically forming an "X" at each fold line. Figures 7 and 8 show our test piece and wings with this technique applied.

(a) Spring wire test piece folded (b) Unfolded test piece

Figure 7: Spring wire with 0.08 inch diameter taped to wing allows for wing to unfold and stay unfolded.

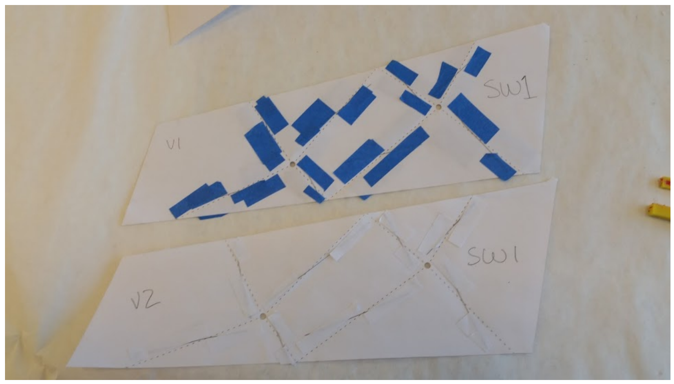

Figure 8: Spring wire wings prototypes, using tape on top and glue on bottom to attach spring wire. Wires are placed 15 degrees from perforated cut.

By this point, we decided to explore a new technique for making a new type of origami glider, different than the one proposed initially. Thought the spring technique seemed to work on a small scale applying it to the wings did not seem to have the intended effect. After reading a paper from Seoul National University in Korea [2], we decided to implement a similar fabrication process where we would take a strip of Mylar, approximately one inch by twelve inches, and wrap it around a metal tube with thermal resistant wire and tape. See figure 9 for visual representation. This Mylar strip would be heated by a heat gun for approximately two minutes and could be used to create a rigid yet flexible structure that could be folded, all while keeping the weight and cost down. Figures 10 and 11 show both a top and bottom view of the proposed prototype plane. We used spring wire on one side of the the wings down the wing along both ends, and let the curvature of the Mylar structure give the wing its shape.

Figure 9: Mylar structure fabrication.

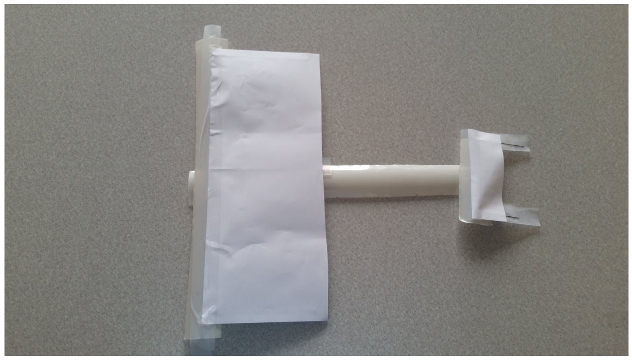

Figure 10: Top view of plane.

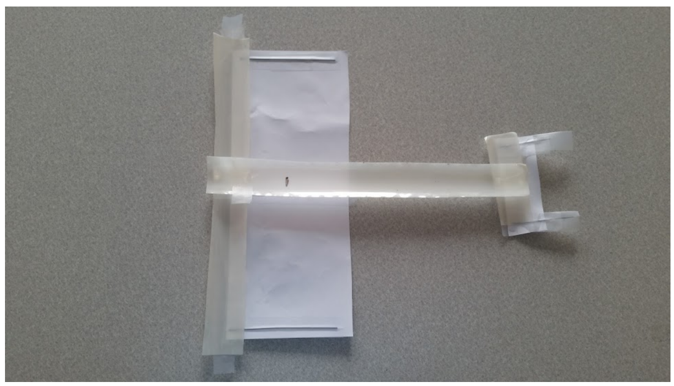

Figure 11: Bottom view of plane.

Potential Future Work

Quantitative testing on which of the two glider designs still needs to be done. This can be done by measuring time flown and distance glided. Motorizing the glider is also an important next step to making the glider a controllable plane. Further analysis should also be done on what other types of materials can be used to make the glider fold easier and more reliably, while also maintaining rigidity and a curved shape. This is a difficult problem to solve, and would probably require consulting with another professor in the materials science space who has experience with self folding structures like shape memory alloys and polymers. As a final note we would like to thank the SAG grant committee for their generous funding of our project and academic development.

References

[1] Origami Airplane Paper Outlines, Professor Christopher Lee Research Lab

[2] Baek, Lee and Cho, Curved Compliant Facet Origami-Based Self-Deployable Gliding Wing Module for Jump Gliding, ASME IDETC/CIE 2016