Between Form and Method

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Abstract

The intent of this thesis was to develop a component system derived from a desired form. Through analysis of the initial form, I gained an understanding of the underlying parameters, principles, and topologies the form exhibited that could then be interpreted into the development of a component system. Through the process of design, utilizing iterative attempts of creating a component system directly mimicking the original form, I began to realize the need to better understand the underlying principles and topologies of the original form. This understanding became the basis in my attempts to assemble components toward a direct copy of the original form. This experimentation led to the realization that direct copy was not achievable. However, the deeper understanding of the principles exhibited within the initial form provided the framework to develop a component system that would exhibit similar results while simultaneously allowing for greater control in the development of a member with a particular desired outcome. The conversation between Form and Method was a continuous dialogue throughout the project: from the form of the initial model and the method of developing a component system based on the principles it exhibited, to the formal expression of the component itself, and eventually to a final iteration that combines the principles of the original construct through the method of assembly based on the form of the component.
To my family.

“Discovery consists in seeing what everyone else has seen but understanding it for the first time.”

~Albert Szent-Gyorgyi
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The transformation and manipulation of a few parameters within a given framework can lead to the development of the legible perception of a seemingly ambiguous construct.
Interested in forming a dynamic space that exhibited features of repetition, movement, and ambiguity, I began constructing models derived from the diagrams on the previous pages by manipulating simple paper strips through the mechanisms of insertion and twisting. Through several iterations I found similar qualities within the sequential movement of the strips that I wanted to emulate on a larger scale. I began working to develop a component-based system that would provide a means to construct these forms with modular elements and at various scales. From this point, the conversation develops between Form and Method: between the form of the overall structure and the method used to define it, as well as between the form of the individual component and the method of analysis and synthesis used to generate it.

A conversation between Form and Method must begin somewhere, with the beautiful potential to continue in either direction. In my process I began with a form. A conceptual model generated by inserting - twisting - and reinserting a paper strip into a base. The base consisted of insertion points that increased sequentially in rotation along one axis while remaining parallel along the other.

The result was a series of arches that bent and twisted with progressively greater intensity. The repetition of the ribbon provides consistency against slight modifications of the arches to define dynamic interior and exterior spaces.
This form is the basis of further investigations to develop a component system; a system that would ultimately allow a controlled construction of desired configurations and twists.
Method
To begin to understand the properties of the twisted ribbon, I developed a jig to construct a larger version of the elements of the conceptual form model. Using the jig I constructed two of the twisted elements.

To serve as a reference base, I constructed a control element with holes spaced at regular intervals. I paired this with a blank element and set both in the jig with a spacer. Using a pin, I marked corresponding holes on the blank. Once punched and connected with screws, the double layer ribbon was able to hold its shape outside of the jig.

In the first experiment using the jig, I constructed a double ribbon with a 90 degree twist. Once removed from the jig, this ribbon lost approximately 15 degrees of twist. This loss could have resulted from several factors including the spacing between the bolts: a tighter spacing may have maintained a greater degree of relationship between the control and the variable pieces; the elasticity of the material; or the imprecise means by which the corresponding holes were made simply using a safety pin.

To compensate in the second experiment, I set the jig at 195 degrees to anticipate a final 180 degree twist. This compensation in setup did produce a twist closer to the desired result, but was still not a full 180 degrees. This demonstrated the need to have greater control over the parameters that affected the outcome of the twist. If I understood these parameters at their core, I could then apply them more accurately towards an end goal.

An understanding of these principles and parameters would also contribute to the greater conversation of how they inform the final overall form of the assembly. The method of analysis used to generate this understanding could potentially lead to developing a form with these parameters.
Figure 30: Working Drawings - Modeling Jig

Figure 31: Photo - Modeling Jig 01

Figure 32: Photo - Modeling Jig 02

Figure 33: Photo - Assembled Double Ribbon Model
Once punched and assembled, I disassembled the double ribbon and plotted the holes as shown in the diagrams to the right.

With a graphic representation of the relationship between the control and variables, I was better able to understand how the twist was developed within the member. The angles of the variable member provided leverage against the orthogonally related and evenly spaced holes of the control member. The angles created narrower and wider distances between punched openings that related to smaller and larger diameters of the arch and twist.

Throughout the development of the component system, the process will continue to return to the basic rotation exhibited in the variable member of this original model. The process is broken down into smaller steps which provided a more indepth understanding of the topologies, and subsequent affects, of composing orthogonal and rotated elements within the same component.
Figure 34: Diagram - Disassembled Double Ribbon Model
Carrying this initial understanding, I began to explore how this construct could be assembled as a series of components. I worked directly with the disassembled diagram of the 195 degree ribbon and developed several iterations of how I thought a component system could be employed.

The forms of these component systems were derived directly from the diagram of the disassemble double ribbon model. They each employed a common component of a quadrilateral defined directly by parameters of the double ribbon. However, the different forms and configurations of each component system result in different appearances and properties within the reiterated assemblies.

The first experiment involved reconstructing the 195 degree twist with a singular ribbon that served as the control element and individual plates that served as the variable element. As one can see, this did not produce a dramatic twist affect, although it retained some of the arch of the original model.

Although the variable elements were easily related to the control elements, the disassembly of the variable ribbon into a series of components reduced the relationship between the variable elements. Inserting a break in the variable member by decomposing it into multiple components removed the direct relationship and thus, much of the resistance between the rotated variable holes. This reduction ultimately depleted the model’s ability to exhibit the intended and desired twist.

In the second experiment, I divided both the inner and outer ribbons into a series of components. The inner and outer ribbon plates were then connected by two perpendicular pieces to form a box. The outer components remained as constants, measuring as 2 inch by 1 inch rectangles. The inner components were derived using two adjacent variable lines.

This iteration also failed to produce the complete twist exhibited in the original model. I believe this is mainly due to the connection method between the control and variable faces. In the original assembly, the faces were held parallel for a greater distance because of their relationship to the washer which distributed a broader surface for parallel adjacency. In this iteration the relationship between the control and variable faces was reduced to the mere thickness of a piece of cardstock.

This iteration was also flawed due to the lack of shear support inherent in the construction of a rectilinear box. This lack of support caused the entire construct to be flimsy and not able to stand on its own.

A third experiment yielded better results in terms of stability, but still lacked the full twist of the original model.

In this iteration the truss system was triangulated to provide resistance against shear forces. The outer components remained as the 2 inch by 1 inch rectangles and the interior components remained as parallelograms defined by adjacent variable lines derived from the original 195 degree construct. In this construct the panel centers were offset to accommodate the triangulation.

This iteration provided the stability needed for the construct to stand on its own, but still did not provide the full twist that was desired or intended. Again, this could be a result of the amount of surface area that is parallel at connection points.
Figure 35: Diagram - Reiteration 01, Plan and Section

Figure 36: Diagram - Reiteration 02, Plan and Section

Figure 37: Diagram - Reiteration 03, Plan and Section

Figure 38: Photo - Reiteration 01

Figure 39: Photo - Reiteration 02

Figure 40: Photo - Reiteration 03
Understanding through these iterations that I needed more control over the manipulation of the variable components in order to produce the desired outcome, I undertook a study utilizing a standard component and altering singular parameters to assess a singular result.

The form of the standard component serves as the means by which the assembly exhibits an arch. Assembling the components with the broad face adjacent to a narrow face results in a narrower dimension on one surface of the assembly, forming the arch. Inserting a rotation in the assembly between adjacent members, as seen in Fig. 46, produces the twisting effect as desired from the original construct, particularly if this rotation originates from the center of the component element, Fig. 47. Inserting spacers into one side of the assembly demonstrates the result of an increase in the diameter of the arch, which also affects the display of a twisting motion in the assembly, although not as drastically over the same distance as the implementation of a rotation between components.

These experiments with the manipulation of the relationships between components and the subsequent affects on the overall form are key steps in understanding the method by which the original double ribbon model can be further analyzed and adapted into a component system. In these controlled experiments, the affects can be more directly compared, providing a broader base for developing the final component system.

This step in the process demonstrates the inherent relationship between Form and Method. With the component shape remaining constant throughout the experiments, the method of manipulation comes into greater focus.

With this procedure, the conversation is more heavily weighted in the direction of Method to Form.
Figure 42: Photo - Trial Component 01, Assembly 01
Original triangle component assembled without manipulations

Figure 43: Photo - Trial Component 01, Assembly 02

Figure 44: Photo - Trial Component 01, Assembly 03

Figure 45: Photo - Trial Component 01, Assembly 04
Original triangle component assembled with slight rotation centered at corner.

Figure 46: Photo - Trial Component 01, Assembly 05
Original triangle component assembled with large rotation, centered at corner

Figure 47: Photo - Trial Component 01, Assembly 06
Original triangle component assembled with rotation centered at center of component.

Figure 48: Photo - Trial Component 01, Assembly 07
Original triangle component assembled with larger rotation centered at corner.

Figure 49: Photo - Trial Component 01, Assembly 08
Original triangle component assembled with a spacer on one side.

Figure 50: Photo - Trial Component 01, Assembly 09
Original triangle component assembled without manipulations
Another round of experimentation was driven by a similar diagram as the triangulated reinterpretation of the double ribbon model. Each piece is angled at a degree sequentially greater than the previous piece resulting in an arch that began to exhibit characteristics of a twist. These are similar to those in the previous experiments, but offer a more consistent and smoother surface.

Working with a better understanding of how the rotation of one connection can influence the twist of the combined assembly, I began experimenting with how to imbed this within the component itself, as opposed to simply applying it to a standard component. As can be seen in Figures 56 and 58, this allowed for a smoother surface within the final assembly. Both of these methods, however, left little room for the manipulation of the arch factor since the dimensions of each component remained the same.

Further iterations of the component system retained the rotational aspect of the triangulated element. This instituted the use of both a top and a bottom chord that could be manipulated simultaneously, yet separately, from each other.
The shape and connections of the component system developed continuously throughout the process. While working to refine the topologies of the system to produce a component that instituted a twist in the final assembly, I also worked to develop a component system that would be easy to manufacture and assemble.

I initially began with a two component system as shown in Assembly Method A. While working with this system, it became apparent that the angled component was difficult to work with and would require more material to manufacture than the following orthogonal iterations. I began exploring ways in which I could produce a more linear component system that would be easier to manufacture and assemble.

With Assembly Method B it became apparent, after several assemblies, that the placement of joints made the ribbon weaker. This was refined by overlapping the top plate components as shown in Assembly Method C. Further refinements were made in Assembly Method D reducing the number of components back to two.

The use of brads was introduced to simulate my intent that the final product would be assembled using bolts, as they can be more easily disassembled and reused. The use of brads also offers more flexibility in the joints, which then correlates to a weaker overall structure when compared to glued joints, particularly in Assembly Method B. However, the flexibility afforded by the brads also allows the twist to be more pronounced than the glued joints.

Further refinement and experimentation is needed to provide stability in the bottom chord. Currently it is very weak in compression because the compressive forces are confined to individual members instead of distributed along the entire length of the truss and through the triangulated central structure.

The development of a connection method was a tangential step in the process of developing a system that could be assembled and disassembled. However, it also provided insight into the topologies between components and the affects of joint strength on the overall form of the final assembly. Weaker joints provided less overall rotation compared to stronger joints such as those in Assembly Methods A and D.

In this instance within the process, the conversation revolves between the overall form, the method by which it is assembled, and the form of the individual component. As demonstrated, the method of assembly is directly related to the form of the component making both of them integral in the development of the overall form.
Assembly Method B: Brad connections

Assembly Method C: Brad connections

Assembly Method D: Brad connections

Figure 64: Diagram - Assembly Method A  
Assembly Method A: Glued connections

Figure 65: Diagram - Assembly Method B  
Assembly Method B: Brad connections

Figure 66: Diagram - Assembly Method C  
Assembly Method C: Brad connections

Figure 67: Diagram - Assembly Method D  
Assembly Method D: Brad connections

Figure 68: Photo - Assembly Method A

Figure 69: Photo - Assembly Method B

Figure 70: Photo - Assembly Method C

Figure 71: Photo - Assembly Method D
In order to understand the effect a particular angle of rotation had on producing a particular degree of twist, I constructed a model with sequentially increasing angles of rotation within the central element. This experiment also demonstrated that there was a threshold to which a component could be angled without losing integrity at the joints. In this model, the optimal degree of rotation appeared to be 8 degrees.

Working with the topologies created by the 8 degree angle, which also resulted in an offset equal to 1/4 the width of the component face, I generated several drawings and models to illustrate and explore the affects of reducing the angle of rotation proportionally to the width of the smallest component face.
Figure 75: Diagram - Topological Relationships of Component Rotation
Combining the knowledge gained through the triangular models with the knowledge gained from the experiment of triangulating the double ribbon reassembly, I developed a system of two components that, when assembled, would exhibit a twisting truss member with two faceted but continuous surfaces.

As with the smaller experiments, I began with a model of increasing angles to understand how the twist was affected by a particular angle. This would also help determine at which angle the system would produce the maximum twist without over stressing the connection points.

After determining that an angle of approximately 8 degrees was the optimal angle, I constructed a series of ribbon truss models in which I adjusted a singular parameter to understand its affect on the outcome of the completed assembly.

The ribbons at right were constructed with components exhibiting an 8 degree angle and decreasing widths of one face component. The decreasing widths created an arch in the second and third iterations as well as de-emphasized the rotation exhibited in the control model.
While still working with Construction Method C and continuing to analyze the topological relationships among the components, I began to explore their relationships through linear drawings. These drawings eventually led me to a better understanding of the relationships between the assembled components that had the greatest effect on the outcome of the final assembly.

The three basic components used maintain three duties within the ribbon construction. Component R is the constant throughout all ribbon constructions. It maintains its width of 1 inch as the baseline.

Component S contains the rotational component at the center fold line that is related directly to the width of Component T.

Component T is usually installed as the bottom chord and decreases in width proportional to the rotation of the center fold line in Component S.
Figure 80: Diagram A - 1 inch Component Assembly
The most important development of the assembly of these components is that of the parallelogram formed by adjacent center fold lines of Component S. These parallelograms provide the contrasting base to which Component T must join. The long and short diagonals of the parallelogram contrast to the equal diagonals of Component T, producing the twist within the ribbon.

Assembling the orthogonal Component T against the parallelogram between S Components forces Component T to exhibit a double-curved surface. The long diagonal of the parallelogram creates a concave curve in Component T and the short diagonal creates a convex curve. These corresponding curves manipulate the face of the component in such a way as to produce the twist seen in the final assembly.

Figure 81: Sketch - Component Assembly
Here the proportions are changed to demonstrate their effects on the composite form. Component T has been reduced to 3/4 of an inch in width but maintains a depth of 2 inches. The rotation in Component S has also been reduced proportionally from a total offset of 1/4 of an inch to 3/16 of an inch, which is equal to 1/4 of 3/4 of an inch.

Having set parameters and topological relationships between the component elements, the form becomes the driving force in the composition of the assembly. The method of analyzing the topologies has led to the understanding of the relationship between the depth of the element and the rotation of the component. Fixing these two parameters provides a given result that can then be decisively implemented within the complete assembly to achieve a desired end form.
Figure 83: Diagram A - 3/4 inch Component Assembly
Again the parallelogram plays a critical role in the outcome of the composite form. Here the dimensions of Component T are reduced in correlation to the reduction in the rotational angle of Component S. This results in a smaller difference between the diagonals of Component T and the corresponding parallelogram, thus resulting in a less prominent twist of the overall composite form.

The reduction in the width of Component T does result in a significant arch of the composite form as the inner diameter is greatly reduced compared to the outer diameter.
Figure 85: Diagram B - 3/4 inch Component Assembly
Employing Assembly Method C and a variable set of parameters based on my understanding of the proportional relationship between the angle of rotation in Component S and the width of Component T, I completed a series of models that demonstrate the effects of altering these parameters.

As the ribbon becomes more arched due to the decreasing width of Component T, it also loses a significant degree of twist due to the diminished rotation in Component S. This decrease is necessary to ensure a more reliable joint within the construct based on the previously determined proportions of the rotation maximizing at ¼ of the width of Component T. Through the development of this series, it can be hypothesized that continuing to reduce the width of Component T would eventually lead to producing a torus in an assembly of like components as described here. As the rotation diminishes, so does the effect of the twist. At some point, the offset would be so minimal that the ends of the assembly would seem to meet, forming a closed torus.

This also leads to the conclusion that the two actions which produced the original form, twisting and arching, act in opposing increments. As the arch of the assembly increases, the twist diminishes and vice versa. This demonstrates a significant difference between using a component system and constructing a twisted arch with monolithic members.
Figure 88: Photo - 7/8 inch Component Assembly, Construction Method C
Width Component T = 7/8", Total offset = 7/32"

Figure 89: Photo - 7/8 inch Component Assembly, Construction Method C

Figure 90: Photo - 13/16 inch Component Assembly, Construction Method C
Width Component T = 13/16", Total offset = 13/64"

Figure 91: Photo - 13/16 inch Component Assembly, Construction Method C

Figure 92: Photo - 3/4 inch Component Assembly, Construction Method C
Width Component T = 3/4", Total offset = 3/16"

Figure 93: Photo - 3/4 inch Component Assembly, Construction Method C

Figure 94: Photo - Comparison of decreasing component widths
Further understanding the properties that generate the twist and arch within the component system and assembly, I again attempted to regenerate the original double ribbon form from which this process began. The first attempt was based on a visual correlation between the original double ribbon model and the sequential paper models to compare which component paper model would best fit the twist and arch of the double ribbon model. The result, shown on the top right, was much more linear than arched and did not produce the intensity of the twist exhibited in the original model.

The second attempt was based on a comparison of the angles and spacing between the graph of the disassembled original model (as shown on page 37) and the angles and spacing of the components that make up the sequential paper models (as shown on page 59). Once again the results did not regenerate an exact replica of the original model. Although the arch was more pronounced, the twist was still much less intense than the original model and appears here as merely an offset between the two ends.

These two experiments culminate this process and represent an ability to understand how the parameters affect the outcomes. Additionally, it holds the ability to enlighten others of the potential to further refine and develop the system as a means to produce a product similar to the original model.

As the process stands at this phase, I believe it has demonstrated the potential to produce forms that exude a sense of repetition and movement. The component assembly of these members accentuates both of these characteristics simultaneously and symbiotically. The rigidity of the orthogonal face components provides a basic visual structure of parallel lines that is then manipulated by the internal twisting of the assembly, thereby resulting in an appearance of converging lines. This manipulation creates a dynamic appearance of movement along the surface of the assembly that is only accentuated by the actual rotation of the entire member when viewed as a complete construct.

The conversation between the Form and the Method of its development and assembly become manifest in this visual play between parallel and converging lines. The conversation continues as the abilities of the underlying principles of this system are further explored and refined.