Chapter

4

Custom Extrusions

In this chapter, you will learn the following to World Class standards:

- **Exploring Custom Engineering Shapes**
- **Analyzing a Previous Shape Prior to Design**
- **Custom Extrusion Design One**
- **Custom Extrusion Design Two**
- **Custom Extrusion Design Three**
- **Reviewing the Steps to Design a Custom Extrusion**

Exploring Custom Engineering Shapes

In the previous chapter, we have visited either on the web or in a customer printed catalog, standard extrusions that are common shapes. Some of those general shapes that we are now familiar with are angles, bar, channels, solid hexagon, pipe, round tube, square tube, rectangular tube, and T-shaped extrusions. We can receive these raw materials at our manufacturing facility in 20 or 40 foot lengths, and perform secondary machining operations to fabricate parts for our assemblies.

Sometimes, we may not be able to find the standard and stocked extrusion for our design needs, so we may call for a custom extrusion, which will meet our drawing specification. The only major consideration that will hinder our organization from purchasing the new custom extrusion is that we need to have the annual production numbers that will use up the hundreds of feet of extrusion required for a minimum run at the factory. For example, we need a new extrusion for a computer heat sink that is 4 inches in length. The Sales and Marketing department plan on selling 10,000 units this year, which means that our yearly usage of the heat sink extrusion will be 4 x 10,000 or 40,000 inches. We will estimate that we can use 95% of the new raw material, since we will lose a small percent from the damaged ends of the extrusion and from the machining process. 40,000 inches divided by 95% and divided again by 12 inches equals 3508.772 feet. This is a good sized production for a custom extrusion, so we can progress witht the design. Only having the knowledge of the size of existing heat sinks mounted on dual core processors, we can have a pretty good feeling that we will be able to use all of the raw material in a custom production run.

Once we get past the problem of accounting for raw material that has to be used annually for a specific part, our next goal is to combine as many shapes into the single extrusion. Since we are designing the custom extrusion, we should incorporate as many features into the part, so we would never have another technician or engineer ask us why we did not place an adjacent component into the extrusion. For example, heat sinks which cool transistors have fins on one side for cooling and an area to attach the transistors on the other. We would want to have the volume of material available which would allow the transistors to be easily attached to the heat sink. For another example, large heat sinks are cumbersome and hard to mount on an enclosure at assembly, so we would be smart to add a volume of metal that would assist technicians in mounting the heat sink. When normally only the electrical engineer is designing a heat sink, the assembly technician, who has to perform the work and the mechanical engineer designing the mounting mechanism may not even have input to these concerns. When we know that the product is going to need a heat sink and an enclosure, try to plan the designs as a team. In our experience, power supplies and heat sinks are given the lease consideration in the design of an appliance or machine, so these are typically the areas of failure in computers and computer related machines, since they are left to the end of the design process.

Another area related to custom extruded extrusion design and heat sinks is air flow. Heat sinks function passively compared to a pneumatic or hydraulic circuit, where a pump moves the fluid throughout the circuit. In other words, as the hot air rises or as the fans pull the air through the enclosure, we should see efficiency in extracting the amount of heat from the heat sink. However, some custom extrusion designs and assembly mounting strategies place the heat sink in a position where they do not perform well and the air does not circulate around the heat sink. In the end, the electrical components do not cool properly, causing them to operate in extreme temperatures, which results in early part failure. These design problems are most prevalent in noncommercial applications, where putting any product on the store shelf is more important than providing excellent quality for the customer. In our experience over the years, customers eventually become more knowledgeable about the products they buy, so building quality into design will help us to avoid excuses in the future.

When planning a custom extrusion involve the Quality Control team. We can never stop urging small, medium and large companies to have a proactive quality control program in their organization, which does not blame the individual who discovers the error in the part, but promotes quality from the part to the assembly to the application. In our studies, we find that the successful companies that have grown throughout the years are built on an attitude of quality. When we create a custom extrusion to our drawing specification, the factory that manufactures the extrusion needs to do know that the part will be inspected dimensionally and geometrically. Most companies are aware that they must meet the dimensional template at incoming inspection but extrusions need to be flat and not twisted. Sometimes, the machinists conducting the secondary operations will find that the extrusion has camber and is not straight although the base and fins are within the dimensions shown in the orthographic view of the engineering drawing. We must work past meeting just a segment of the dimensions and watch how the part maintains its measurements for the length of the extrusion. Not maintaining the flatness or not avoiding twist in the material will probably cause problems during machining and at assembly.

Custom extrusions can be made out of plastic as well as the typical aluminum. When measuring large plastic components, we could always report the bigger plastic wraps and extrusions as being out of tolerance when measuring them at the incoming parts table in the shipping and receiving department. Plastic parts are more susceptible to thermal expansions and the heat of the manufacturing plant, so dimensions and tolerances are only applicable with an a controlled temperature range. Incoming parts quality control inspectors will examine plastic components in a temperature controlled room to get accurate readings on whether the large custom extrusion actually meets the drawing specification. The temperature for the part inspection should be in the notes on our extrusion drawing.

When we were working with the basic engineering shapes, we would have to admit that they were truly rudimentary in their silhouette such as squares, tees, circles, hexagons, L-shapes and U-shapes. Today, we have products where the material in the structure form a complex pattern which allows an extruded beam holding the weight to have thinner wall thicknesses and smaller outside perimeters. One of the reasons we can achieve this is because we can add detail in the shape of the extrusion. Adding a complexity to the pattern such as a angles and circles will result in a stronger design.

The process would not be difficult, if we were asked to design a custom extrusion for any product we find in our environment. A good assignment for architects, designers and engineers is to find the custom extrusions in electrical or mechanical products in our homes and business. We find the custom extrusions most prevalent in the following areas:

- Computer heat sinks
- Aluminum window framing
- Storage shelf framing
- Electrical enclosure framing

An great way to experiment with custom extrusion design is to replace an existing basic shape in a product with a smaller custom form.

Analyzing a Previous Shape Prior to Design

We are going to conduct an exercise, where we replace a large profile standard extrusion with a smaller, and more compact custom extrusion that is just a strong and less expensive to produce. In our problem, we are going to replace a 24 inch long, 2 by 2, 1/8 inch walled aluminum tube with a similar material, so we only will examine the bending moment and we do not have to examine the modulus of elasticity. We will be able to use our Computer Aided Design (CAD) program to perform the calculation.

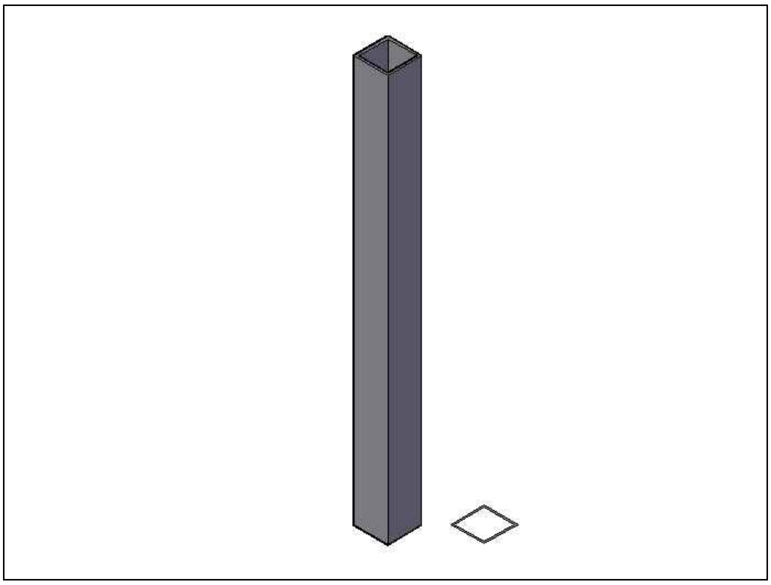
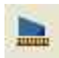


Figure 4.1 – Analyzing the Previously Used Column

In a drawing file, we put the 3D model of the standard extrusion that is a 24 inch long, 1/8 inch walled aluminum tube measuring 2 by 2. We use the Section function on the command line to remove a region of a closed polyline representing the cross section of a solid. After moving the cross section from the tube, we will use the area command to retrieve information regarding the amount of square inches in the region. We may use the information later in the process.

The Area function on the Inquiry toolbar gives the user the area of a solid after specifying “O” for object. If architectural units are set, the answer is given in square inches and square feet. If the object is a circle or Polyline, the perimeter is given.



```
Command: area
Specify first corner point or [Object/Add/Subtract]: o
Select objects:
Area = 0.9375, Perimeter = 15.0000
```

Figure 4.2 – Analyzing the Area of the Region

Next, we will utilize the Massprop command on the Inquiry toolbar to give us the moment of inertia or bending moment for the tube. This number shown in units to the fourth power represents the capacity of 3D solid to resist bending when the centroid is at 0,0,0 point. For solids designed in inches, the moment of inertia is in inches to the fourth power. For metric drawings, the answer is in millimeters to the fourth power. We know this value as the principal axes of inertia, which have their origin at the center of gravity.

In figure 4.3, we can observe that the volume of the aluminum tube is 22.5 cubic inches and that the moment of inertia of the extruded tube is 1093.24 inches to the fourth power in both the X and Y axis. Since our custom extrusion will be made from the same material, we are looking for a smaller volume and similar bending moment for our design.

```
----------------   SOLIDS    ----------------

Mass:                        22.5000
Volume:                      22.5000
Bounding box:             X: 50.9331   --   52.9331
                          Y: -2.8431   --   -0.8431
                          Z: 0.0000  --  24.0000
Centroid:                 X: 51.9331
                          Y: -1.8431
                          Z: 12.0000
Moments of inertia:       X: 4409.6717
                          Y: 65016.9021
                          Z: 60786.5738
Products of inertia:     XY: -2153.6073
                         YZ: -497.6261
                         ZX: 14021.9492
Radii of gyration:        X: 13.9995
                          Y: 53.7554
                          Z: 51.9772
Principal moments and X-Y-Z directions about centroid:
                          I: 1093.2422 along [1.0000 0.0000 0.0000]
                          J: 1093.2422 along [0.0000 1.0000 0.0000]
                          K: 26.4844 along [0.0000 0.0000 1.0000]

Write analysis to a file? [Yes/No] <N>:
```

Figure 4.3 – Analyzing the Volume and Moment of Inertia of the Solid Tube

We are going to design at least three different custom extrusions and analyze them against the original solid shape. We should not expect that we will the correct answer the first time, so we are prepared to make modification to tweak the design into specification.

Custom Extrusion Design One

In our first design, we will employ material coming from the mid span of the extruded wall, because we believe that our new shape will be internally stronger. We are only making the tube 1.500 inches square and the wall thickness is now only 0.100 inches thick. Instead of bringing the internal supports together at the middle of the tube, we will place a circular tube in the center to support the stress.

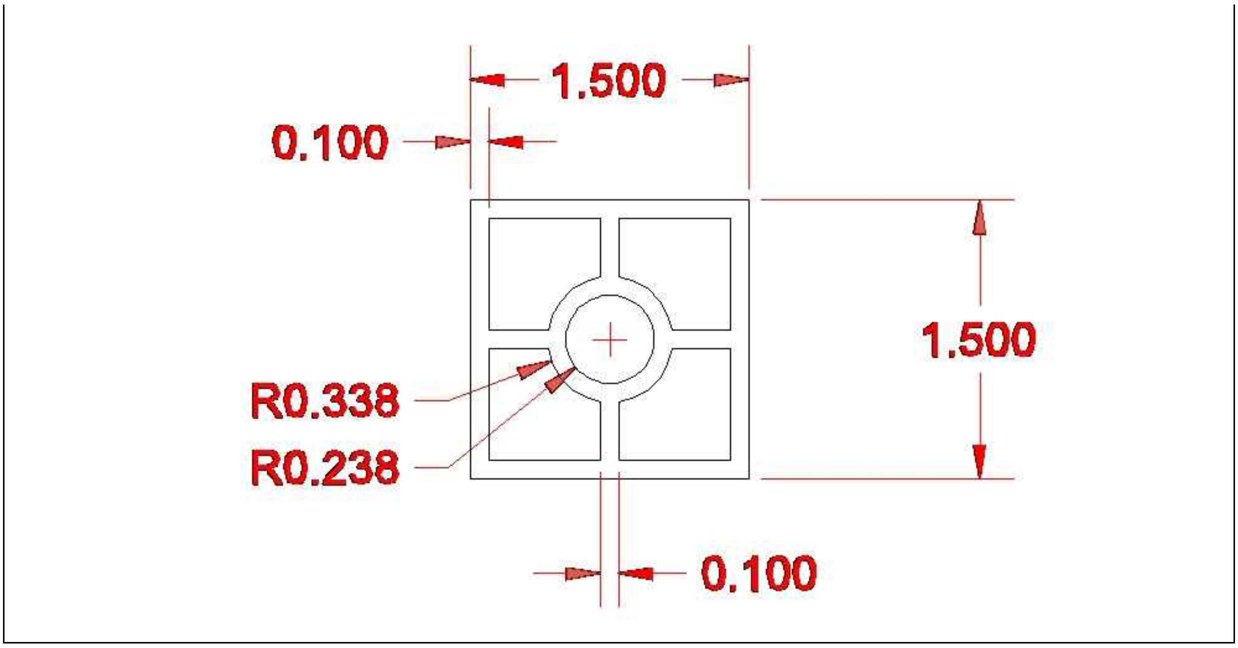
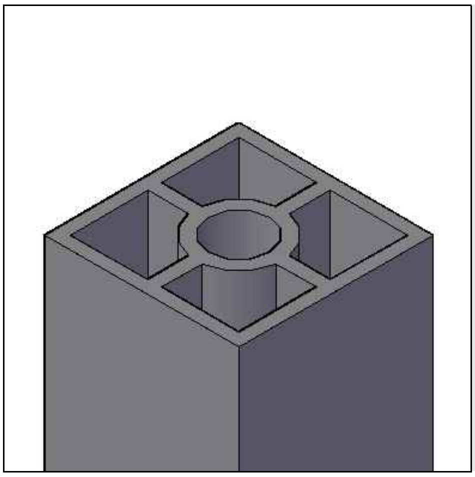


Figure 4.4 – The First Design Attempt

After drawing the shape as shown in figure 4.4 and extruding the solid, we find that the volume of the custom extrusion is 28.787 cubic inches for the 2 foot long section and that the moment of inertia of the three dimensional shape 1002.77 inches to the fourth power. We can see in figure 4.5 that our idea to place an internal circular tube into a rectangular tube is very close to a solution.

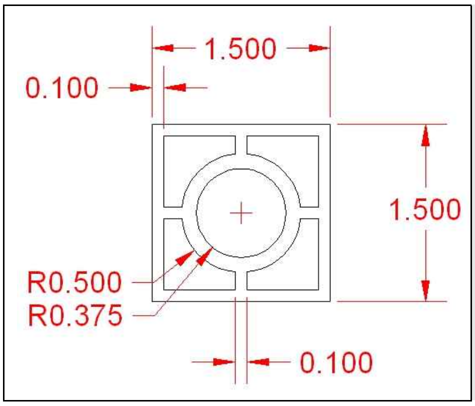


---------------- SOLIDS ----------------

Volume: 20.7873
Principal moments and X-Y-Z directions about centroid:
I: 1002.7671 along [1.0000 0.0000 0.0000]
J: 1002.7671 along [0.0000 1.0000 0.0000]
K: 9.9545 along [0.0000 0.0000 1.0000]

Figure 4.5 – The First Design Attempt

We went through multiple increases in the radius of the circular tube in the middle of the rectangular tube. When we placed in a 1/8 inch thick tube with an outside diameter of 0.50, we had an answer to this approach using the silhouette in figure 4.5. Because we are relatively close to the original design, we did not have to work too long to get an answer. Our result to the first attempt in shown in figure 4.6.



Volume: 23.1347
Principal moments and X-Y-Z directions about centroid:
I: 1115.9244 along [1.0000 0.0000 0.0000]
J: 1115.9244 along [0.0000 1.0000 0.0000]
K: 10.9183 along [0.0000 0.0000 1.0000]

Figure 4.6 – The Solution to the First Design Attempt

Custom Extrusion Design Two

In our second design, we will place the internal supports at the corners instead in the middle of the spans as we did in the first design analysis. We still suppose that our new shape will be internally stronger, so we are only making the tube 1.500 inches square and the wall thickness is still only 0.100 inches thick. Once more, we will bring the internal supports together at the middle of the tube, and we will place a circular tube in the center to support the stress. In the drawing, we start the circular shape at an outside radius of 0.225 as shown in figure 4.7.

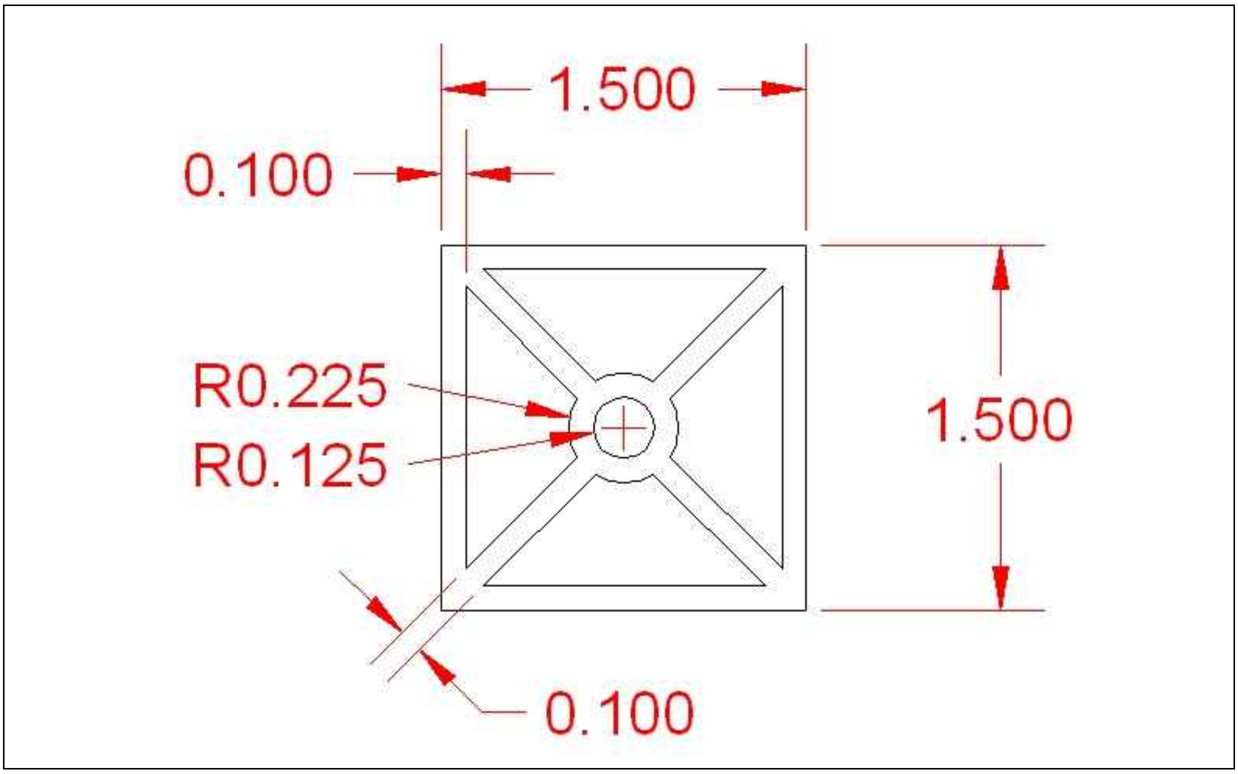
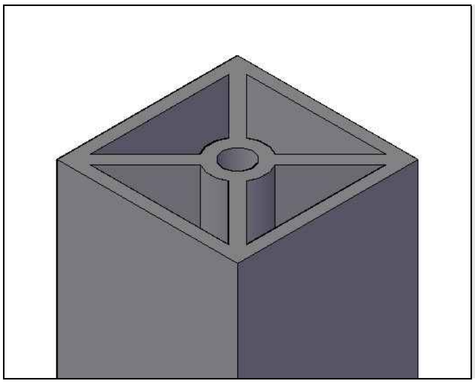


Figure 4.7– The Second Design Attempt

Without trying multiple designs, we discover from the Mass Property results that the corners need to be supported in order to strengthen the custom extruded shape. Our design is almost at the 1093.24 inches to the fourth power. A slight increase in the 0.225 radius will bring the moment of inertia into acceptable limits.



```
----------------   SOLIDS   ----------------

Volume:       22.5215
Principal moments and X-Y-Z directions about centroid:
              I: 1086.6204 along [1.0000 0.0000 0.0000]
              J: 1086.6204 along [0.0000 1.0000 0.0000]
              K: 11.1728 along [0.0000 0.0000 1.0000]
```

Figure 4.8 - The Solution to the Second Design Attempt

Custom Extrusion Design Three

In the third and final attempt to create a custom extrusion for the 2 by 2 aluminum tube, we will decrease the outside measurement to 1.250 by 1.250. We also diminish the wall thickness of the outside wall and the circular tube for internal support. We decided to examine the supports holding the corners and bring them to the center as shown in figure 4.9.

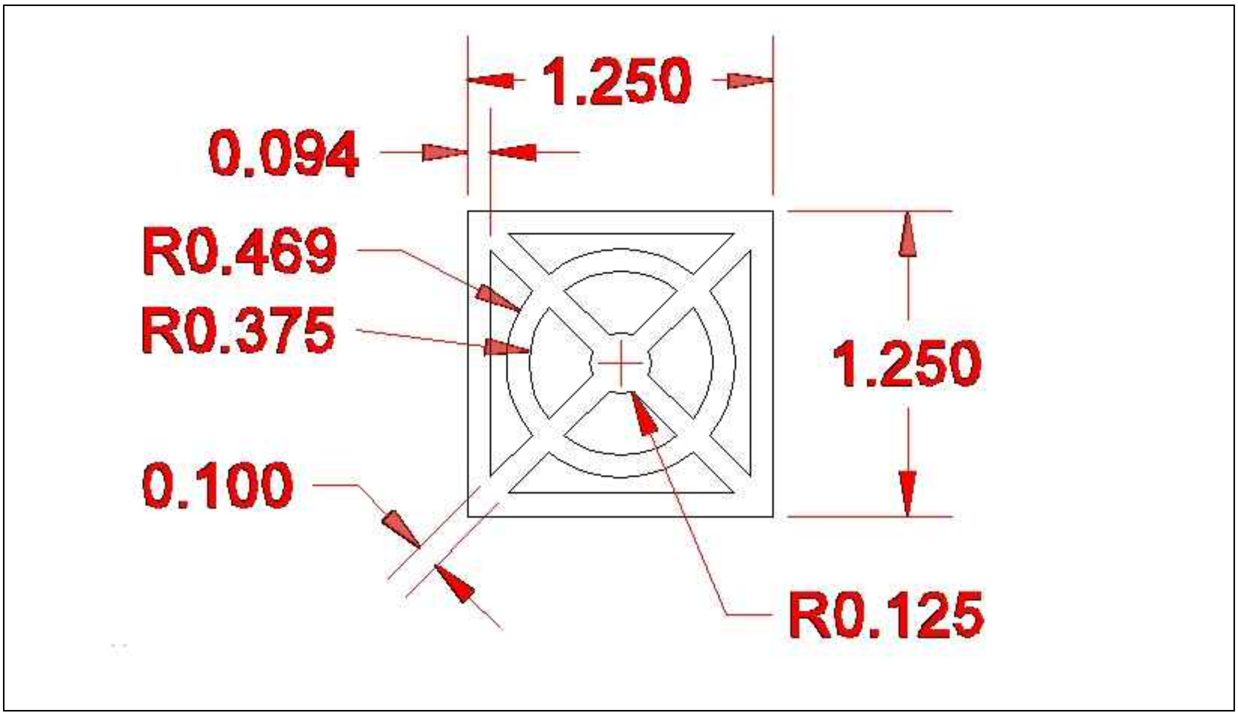
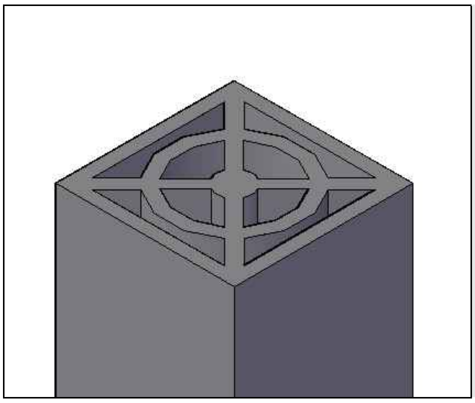


Figure 4.9 - The Third Design Attempt

The solution to the third attempt is very close to an answer and from previous experience; we know that the outside radius of the internal circular tube can be increased slightly to give us a 1093 inches to the fourth power moment of inertia.



---------------- SOLIDS ----------------

Volume: 22.2976
Principal moments and X-Y-Z directions about centroid:
I: 1073.6903 along [1.0000 0.0000 0.0000]
J: 1073.6903 along [0.0000 1.0000 0.0000]
K: 6.8066 along [0.0000 0.0000 1.0000]

Figure 4.10 - The Solution to the Third Design Attempt

This third solution is the best so far. By using a much smaller support column in the design, we will have more cubic inches of usable space inside of an enclosure or shelving unit while still holding the same weight. The new support tube requires less corrosion protection and finishing paint. If we are shipping the components to our sister plant, we can package more columns in the same size container or ship the same number pieces in a smaller box.

Reviewing the Steps to Design a Custom Extrusion

This project to design a custom extrusion replacing a standard extruded shape is a great exercise for architects, designers and engineers to better understand the design process. We have always admired individuals such as Thomas Edison, who spent hundreds of hours and experimented with thousands of techniques in order to achieve the desired outcome. We only went through a handful of configurations to gain knowledge as to what shapes would support weight similar to a simple extruded silhouette. As designers, we need to push ourselves past previous design limitations and to explore new ideas and concepts to make the product better. The majority of that effort is going to be in meticulous work where we fight the urge to give up and settle for an easy answer. Great architecture, design and engineering involve exploration and dedication in examining whatever project task we are assigned. The lessons we learn today such as in this chapter will help us solve bigger challenges months or years from now.

Remember the steps to adding a custom extruded shape to the organization's list of raw materials.

1. The amount of parts being made annually should use up the production run of a custom extruded material.
2. Whenever possible, mechanical and electrical engineers should work with the production engineers combining multiple shapes into one extrusion, making it multifunctional.

3. Bringing a custom extrusion into a manufacturing facility requires a proactive Quality Control program to inspect incoming material that meets the drawing specification.
4. Mechanical engineers should be familiar with the most of recent computer design tools allowing them to create an extruded shape that meets the design criteria while using a pattern to reduce overall wall thicknesses and reduce weight when possible.

Now that we have the skills to produce a custom extrusion, try the next World Class CAD Challenge.

*** World Class CAD Challenge 08-3 * - Save and close the extruded aluminum angle drawing file. Create a new file and make a part drawing for a 1/8 thick wall by 1.50 leg by 2.50 wide channel, dimension, and place the border and notes in less than 30 minutes. Continue this drill three more times, for a round tube, t-shape extrusion and a rectangular tube, each time completing the drawing under 30 minutes to maintain your World Class ranking.**