The Frame – Detail 7

The frame is the last part to work on and is another straightforward milling job (Photo 6). Shown in Photo 7 is a close-up of the air entry, air exit, and pivot hole.

Modeling the Frame

Step One

Create a new sketch on the right plane and draw the outside profile of the frame as shown in Screenshot 30. Finish the sketch and extrude it using Mid Plane to a thickness of 1/2”. Using the Mid Plane option will extrude the sketch to a total thickness of 1/2”, but half in one direction and half in the other. This allows us to keep the right plane centered in the middle of our model.

Step Two

After the frame is extruded, use Hole Wizard to add the 10-32 mounting holes on the bottom surface of the frame as shown in Screenshot 31. The spacing is 2-1/2” and they should be centered with respect to the overall length of the outside profile.
**Step Three**

Next, we will add the crankshaft hole using Hole Wizard. Select the front surface of the part and add a 1/4” Through All simple hole (Screenshot 32).

*Screenshot 33* shows what the frame should look like at this point.

**Step Four**

Now, we will add the two air holes. Using Hole Wizard, select the front surface of the frame and choose a simple 3/32” hole to a depth of about 3/8” (*Screenshot 34*). These holes do not want to break through!

**Step Five**

The next hole will be the pivot hole for our cylinder. Using Hole Wizard, select the front surface of the frame and add a clearance hole for a 10-32 socket head cap screw (*Screenshot 35*). A tight fit works best here; it helps to reduce the amount of play between the air holes and cylinder.

**Step Six**

Lastly, we need to make our air connections. The hole on the top of the part is a 10-32 tapped hole for an air fitting. This hole can be made to suit whatever you have available. The hole on the left face of the frame is another 3/32” hole for exhaust (*Screenshot 36*). You can actually do these either way; for example, having the exhaust on top and the air entry on the left face.

*Screenshot 37* is a cross-section of the part at the air hole locations. The majority of the frame was done using the Hole Wizard feature.

**Assembly Modeling**

After all of your components are modeled for the engine, you can create an assembly (*Figure 1*). The assembly can be created more or less how you would actually build it – without the hammering, glue, solder, or the other typical assembly techniques. SolidWorks requires
Mates to define the relationship between components. A working knowledge of 3D modeling assembly would help for this part of the process.

First you need a Base Component. The Base Component is the first component in an assembly. It should be the main component that all other parts assemble to and is usually stationary. Consider the frame to be the “anchor” for the entire engine. I inserted the frame into the assembly and mated the frame origin with the assembly origin (Screenshot 38). This ensures that all of our default planes are lined up properly!

When you insert the first part into an assembly and place it anywhere it becomes automatically fixed. If you do this without fixing the part origin to the assembly origin then it can potentially create a headache later on down the road as the assembly gets larger.

To fix the part origin to the assembly origin you first want to make sure that the origin is shown in the graphics area of the assembly. If not, navigate to the View drop-down menu and select Origins.

When inserting a component, in this case the engine frame, try to hover the frame origin over the assembly origin. You should see a double origin symbol when you do this. Try not to left-click and drop the frame until you see the double origin symbol. A lot of my students try to line up the mouse cursor with the assembly origin but that does not work. You have to make sure the part origin and the assembly origin are on top of one another. When you see the double origin symbol you can then left-click and place the part. It becomes automatically fixed to the assembly origin. You should see an (f) in parentheses to the left of your component in the feature tree.

If you do insert the first part into an assembly and it becomes fixed in the wrong position you can always right-click and select Float. This removes the fixed relation and will allow you to mate the part manually as you would with any component.

The next part we can add is the crankshaft (Screenshot 39). Navigate to Insert Component, select the crankshaft, and drop it into the graphics area as shown.
Using the Mate tool on the assembly toolbar, select the outside diameter of the crankshaft and the crankshaft bore (highlighted in blue) as shown in **Screenshot 40**. SolidWorks assumes you are looking for a concentric Mate, and in this case the program is correct. Select the green check mark to add the Mate.

Adding this Mate allows you to slide the crankshaft back and forth within the bore. We have not prevented the crankshaft from spinning, nor did we limit its side-to-side movement. This is what Mates do; they limit degrees of freedom between components. If you want the crankshaft to rotate, then you would not add a Mate that prevents it from rotating. In our assembly, we want the crankshaft to rotate; we want to see our engine operate as it should.

At this time, just slide the crankshaft into the approximate position shown in **Screenshot 41** so we can...
position the crankshaft in the next step when we add the flywheel.

Insert the flywheel into the graphics area (Screenshot 42). No, this flywheel does not reflect the one we constructed earlier; it is another one I found on my computer. The nice thing about building an engine in 3D is we can quickly change designs, colors, and materials with the click of a button. There is not an “Add Metal” button in the real world so take advantage of the CAD system!

Add a Mate between the crankshaft’s outside diameter and the flywheel bore as shown in Screenshot 43. SolidWorks assumes a concentric Mate, as it should. Your flywheel may reposition itself as needed to satisfy this Mate. Hit the green check mark to add the concentric Mate.

Now select the front surface of the flywheel. Select the Mate tool from the Assembly toolbar. Select the back face of the frame as your second Mate selection (Screenshot 44). This Mate creates a coincident Mate between the front face of the flywheel and back face of the frame. Your flywheel should be able to rotate but not come off the frame.

Next, add the crank disk and drop it into the graphics area. Add a concentric Mate between the crankshaft and the crank disk.

Add a coincident Mate between the front face of the crank disk and the front face of the crankshaft as shown in Screenshot 45. Then, add a coincident Mate between the back face of the crank disk and the front face of the frame. This positions the crankshaft and crank disk in its correct location.

The next few steps involve adding motion between the flywheel, crankshaft, and crank disk.

Add a coincident Mate between the front plane of the crankshaft and the front plane of the flywheel (Screenshot 46). This makes both planes flush with one another so that when one component is rotat-
ed the other has no choice but to follow. Add the Mate and rotate the crankshaft to view the results. Add another coincident Mate between the crankshaft and the crank disk. This ensures that all three components (the crankshaft, crank disk, and the flywheel) rotate together.

Insert the cylinder into the assembly (Screenshot 47). First, add a Mate between the front face of the frame and the surface of the cylinder with the air entry hole. Also add a concentric Mate between the pivot hole in the cylinder and the pivot hole in the frame. Do not add any additional Mates; we want the cylinder to pivot.
Add the piston into the assembly and then add a concentric Mate between the piston's outside diameter and the piston bore in the cylinder. If the piston is inserted backwards, simply hit the Flip Mate Alignment button and position it approximately as shown in **Screenshot 48**.

Before we finish mating the piston, we need to install the crankpin. Insert the crankpin into the assembly and mate the outside diameter of the crankpin to the offset hole in the crank disk (**Screenshot 49**).

Mate the back face of the crankpin to the back face of the crank disk (**Screenshot 50**). This may be tricky because the back face of the crank disk is flush up against the front face of the frame. You may want to practice deleting Mates, moving components, and adding Mates to achieve the desired results. As mentioned earlier, when creating the crank disk, a sub-assembly of the crank disk and crankpin could have been made. Try creating the sub-assembly yourself and then insert that into your final assembly. Like anything else, assembly creation requires practice. On the bright side, in the 3D world it's not costing us scrap!

Finally, add a concentric Mate between the crankpin and the hole in the piston (**Screenshot 51**). Left click on the flywheel and rotate it; your assembly should come to life! If your engine does not move, you have over-defined the assembly and added an extra Mate that limits the degree of freedom of some component. If some of your components float off into the graphics area, you did not add enough assembly Mates.

At this level you can rotate the model to view any discrepancies (**Screenshot 52**). If you notice

<table>
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<th>Description</th>
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<tr>
<td>A</td>
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<td>Flywheel Setscrew, 6-32 x 1/8&quot;, McMaster-Carr No. 91375A142 or 8-32 x 1/8&quot;, McMaster-Carr No. 91375A188</td>
</tr>
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<td>B</td>
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<td>Pivot Screw, 10-32 x 1-1/4&quot; SHCS, McMaster-Carr No. 91251A349</td>
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<td>C</td>
<td>2</td>
<td>Washer, No. 10 flat, McMaster-Carr No. 91081A127</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>Washer, 1/4&quot; flat, McMaster-Carr No. 91081A129</td>
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<tr>
<td>E</td>
<td>2</td>
<td>Mounting Screw, 10-32, style and length can vary</td>
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<td>1</td>
<td>Pivot Spring, Ø1/32&quot; wire, 3/8&quot; OD x 1/2&quot;, 3/32&quot; pitch</td>
</tr>
</tbody>
</table>
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interference, you can revise your models to fix any issues before it gets built!

Now that the working components of the assembly have been mated and the assembly is fully operational, you are free to add details: fasteners, colors, materials, logos, and even a custom base! Using 3D modeling, you can now model a base using any shape, material, and color you like. You can change your mind whenever you want and never have to worry about having the stock in your shop.

Photos 8 and 9 show the completed engine, ready for air. Photo 10 is another see-through engine with an aluminum base and a slightly different flywheel. One of my students was not happy with the outcome of his engine frame for a different project and threw the frame into the scrap bin. I decided to clean it up and use it as the base for this engine.

For those of you who love not only building model engines but designing your own, 3D modeling is the way to go. Even ask some of the “Old Timers” who have finally came around to trying out a 3D CAD system. The first thing they will say is, “It’s really cool!” 😃
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