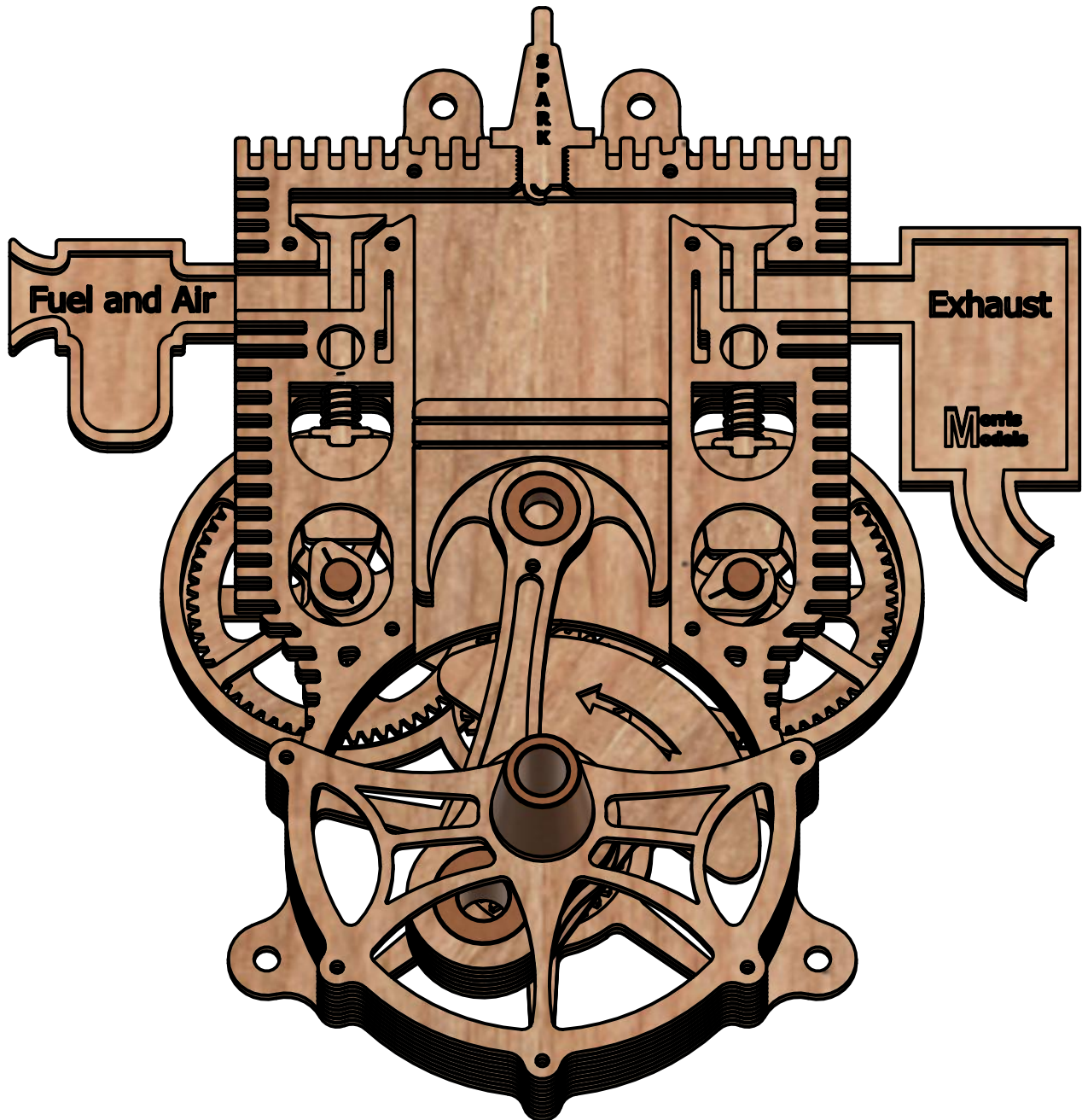


Flat Flathead

Manual

Build a stylized flattened cutaway to understand and illustrate how a four stroke internal combustion engine works.



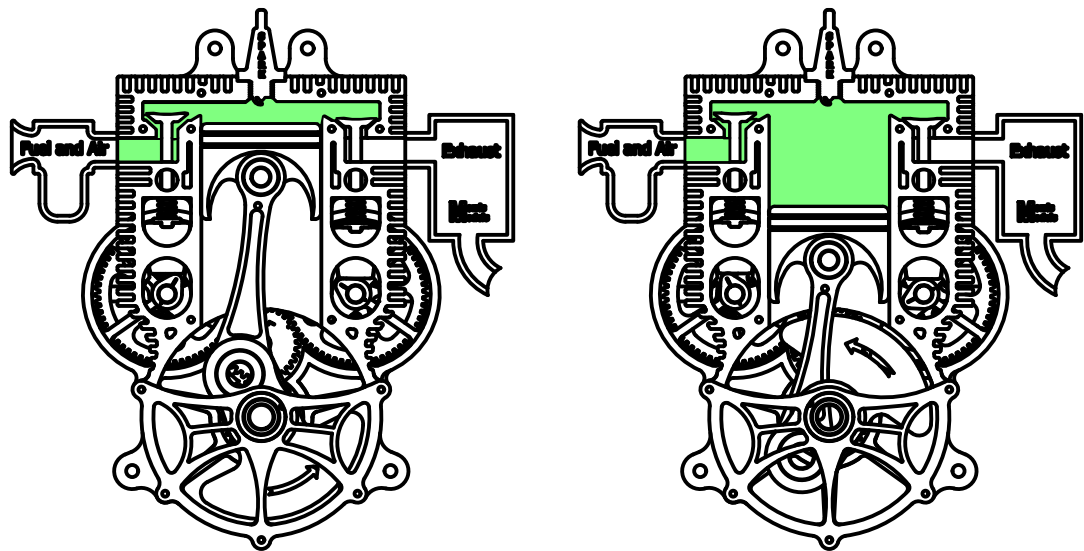
Background Information

You are about to put together a cutaway model engine. It is designed to help you understand how a real four stroke engine works, but it is not a real four stroke engine. It has been rearranged so that all the parts are easy to see. It has also been flattened so that it is cheaper to produce and easy to hang on a wall or keep in a desk drawer.

The idea behind the four stroke engine was invented in 1861, but the first working engine was not built until 1876 by a man named Nikolaus A. Otto. Since then, four stroke engines are also known as Otto cycle engines, and they all work the same way.

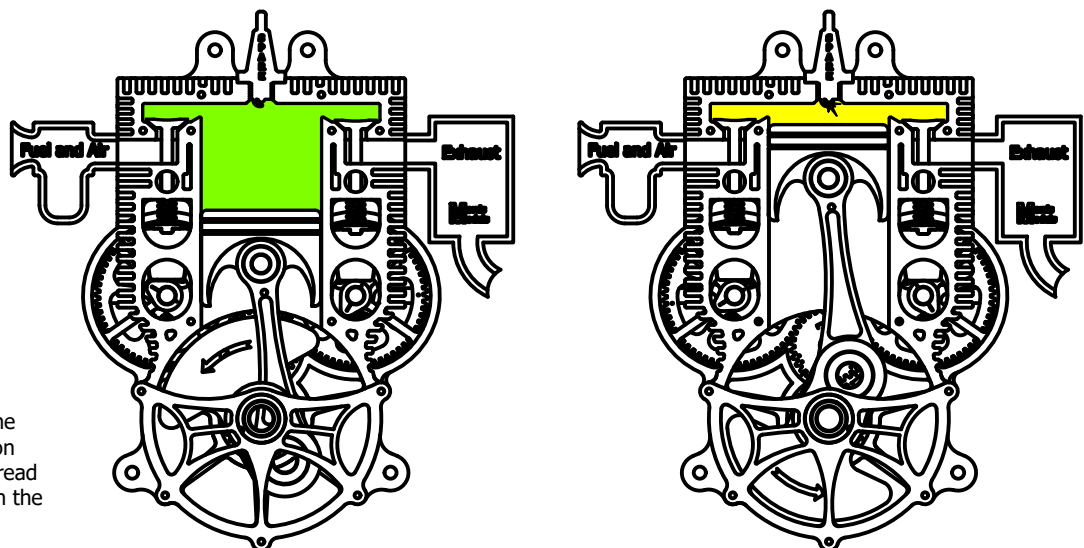
Intake:

The cam forces the intake valve open, and lets fuel and air flow in. At the same time, the crank pulls the piston down, which pulls the fuel and air into the cylinder.



Compression:

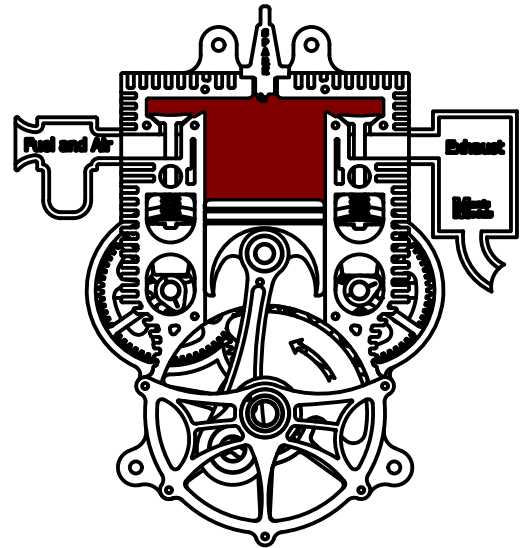
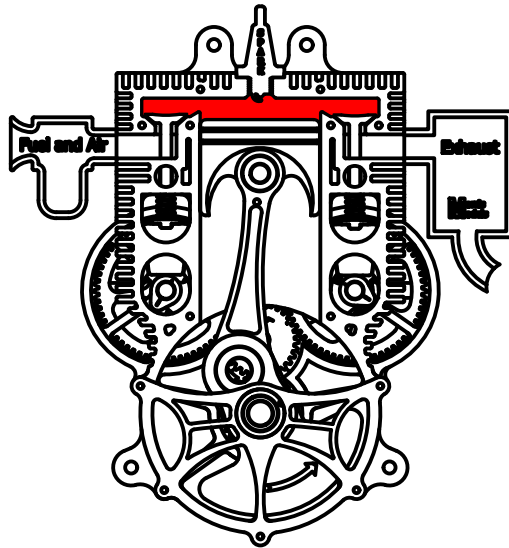
The cams allow the valves to shut. Nothing can enter or leave the cylinder. The crank forces the piston up, squeezing the fuel and air. The fuel and air gets hot, and is almost ready to catch fire. The spark plug makes a spark near the end of the compression stroke, and flames spread through the mixture in the cylinder.



Background Information

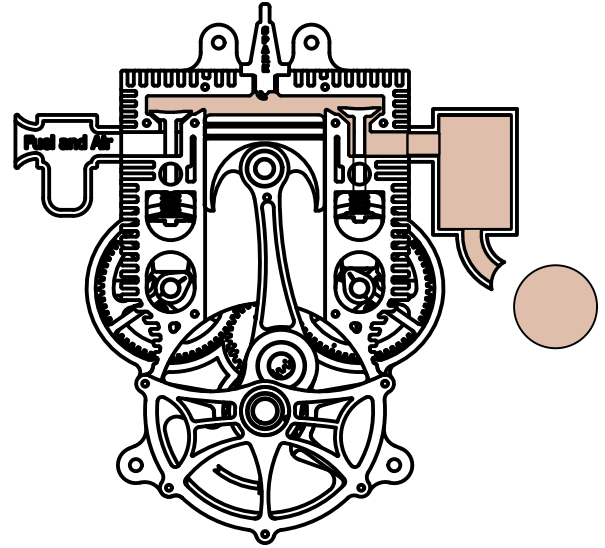
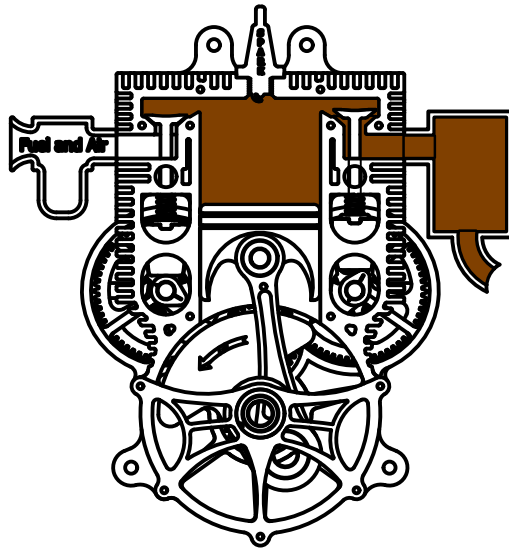
Power:

As the fuel and air burn, they get very hot, causing them to increase in pressure. The high pressure in the cylinder pushes downward on the piston, which turns the crank on the crankshaft. This is the only portion of the Otto cycle where power is produced.



Exhaust:

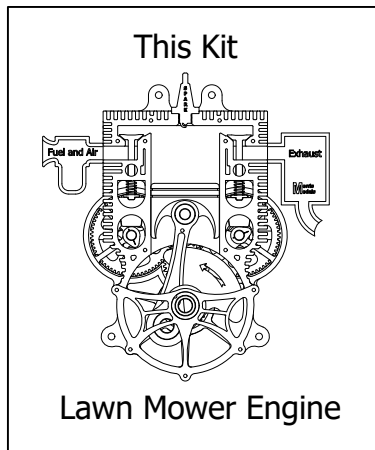
The cam forces the exhaust valve to open. The crank forces the piston to move back upwards, pushing the already burned air and fuel (now called exhaust) out of the exhaust pipe. Most engines have a muffler to make this quieter.



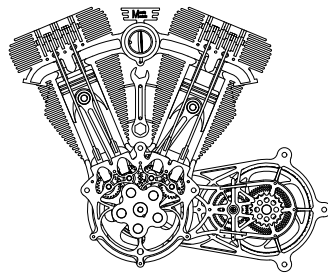
These four strokes happen over and over again, many times each second. Since the engine only makes power during one of the four strokes, a flywheel is used to keep it turning during the rest of the time. Most larger engines have more than one cylinder. Each cylinder goes through the same INTAKE - COMPRESSION - POWER - EXHAUST strokes. However, the engines are usually set so that each stroke happens at a different time in each cylinder. For example, a four cylinder engine has one cylinder doing intake, one doing compression, one doing power, and one doing exhaust at any particular time. This lets it run much more smoothly.

It is the differences in sizes, numbers, and shapes of cylinders and the valves that makes four stroke engines so interesting and different from each other. A single cylinder engine like this one is simple to understand and cheap to build. Visit www.morrismodels.com to see models with different arrangements.

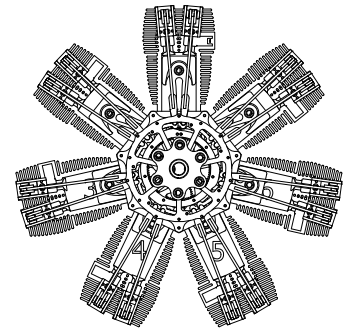
Before you begin



Lawn Mower Engine



Motorcycle Engine



Airplane Engine

Most of this kit was cut out of baltic birch plywood on a laser cutter. Plywood is a natural product, and every peice is different. Because of this, the laser cannot cut every peice perfectly. This means that in some places, there is smoke and scorching. In other places, the wood did not cut completely and there are splinters hanging on the edges. The more time you spend preparing your parts, the better your completed model will be.

You should begin by making sure that all the parts are included. Look over the rest of the steps in this manual, and find all the parts for each step. Check the parts to make sure that they are in good condition. Minor damage can be repaired with glue. Splinters should be removed using an X-acto type knife and sandpaper. Scorched marks should be lightly sanded off. If any parts are badly broken or are missing, you can get replacement parts from www.morrismodels.com.

A few of the parts for this kit are cut from round pieces of wood called dowel rods. These form the engine shafts. These also should be sanded for splinters. The ones that are included in this kit are basic cylinders. If you have access to tools, they can be made to look a little more realistic if you drill holes in some of them and cut or sand a bevel in the front shaft. The parts shown in this manual have had this done, but this step is for appearance only, and is completely optional.

This engine is designed to be assembled with any type of wood glue. I personally use Elmer's "Glue-All" glue. Do not use Elmer's "School Glue." It will not work. Whatever glue you use, use only enough glue to stick the parts together. Extra glue will squeeze out from between the parts and stick the engine together in places where it should not. Any glue that does squeeze out from between parts should be wiped up with a damp cloth while it is still wet.

Many of the plywood parts have small 1/8" holes. These holes are to help line up the layers. As you work, try to keep the glue away from these holes. When you put on a new layer, push short 1/8" wood dowel pins into the layers to help you line them up. These are called alignment pins. You should remove the alignment pins after the glue has had a few minutes to dry.

Many people ask if they can varnish, paint, or stain the engine. I do not recomend using paint or varnish, but oil-based finishes or stains are appropriate. Assemble the engine before using them. Another alternative is to use water-based markers. You can color each part after it is assembled. These parts absorb a lot of marker ink, so it will take quite a few markers to do the job.

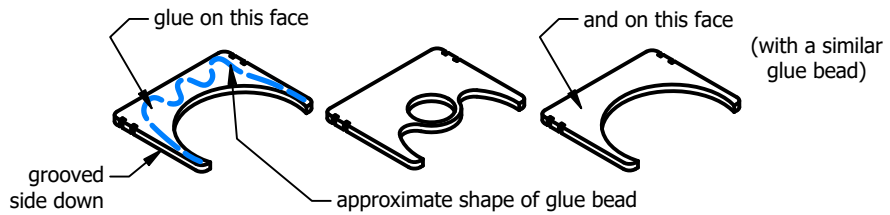
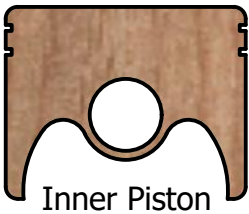
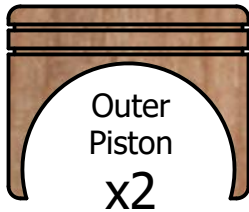
Real engine use oil to keep them sliding smoothly. This wooden engine model would be ruined with oil. Most people use wax when assembling these wooden engine kits to help the parts slide smoothly. This step is optional. I have used candle wax and I have used colored crayons. Either of these will work fine. So does paraffin wax.

This manual shows how to build the engine step by step. Sometimes it is hard to explain things in a manual, but easy to understand it on a video. At the www.morrismodels.com web site, you can find a link to an assembly video that shows the same steps that are in the manual. Use this video if you prefer, or use the video to view any steps where you have trouble understanding the manual.

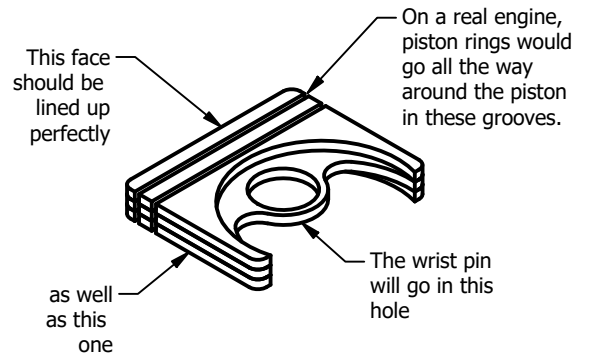
I hope you enjoy building this kit. If you do, you may want to consider taking apart an old lawn mower engine. You will find that it has very similar parts to what are in the kit - except that the parts are round. You may also want to consider building some of the other model kits on the web site as well.

Step 1: The Piston

New Parts:



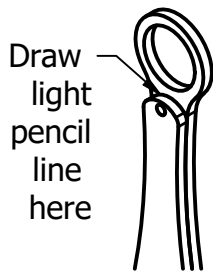
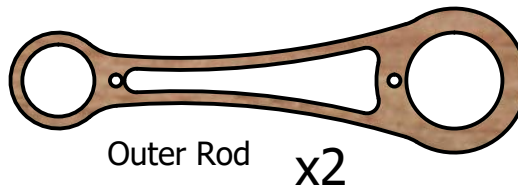
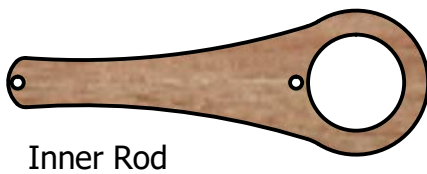
Set the two outer pistons grooved side down on your work table. Lay the inner piston between them. Lay out a light bead of glue on the ungrooved side of the two outer pistons. Set the inner piston on top of one of the outer piston, making sure that the edges line up perfectly. Turn the other outer piston over, and set it on top of the stack, again



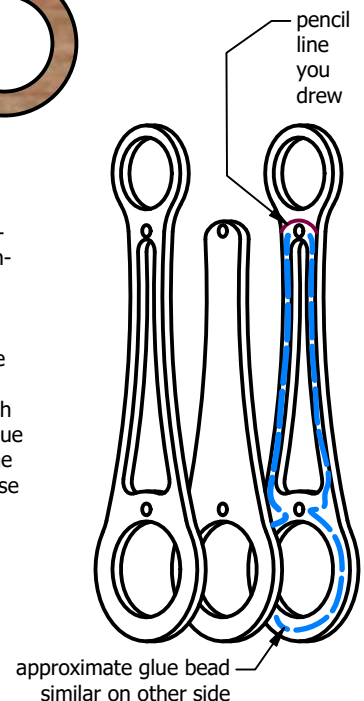
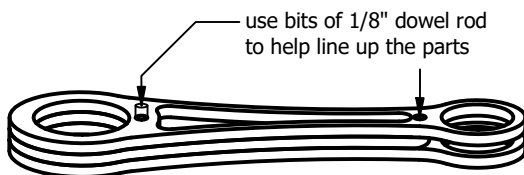
making sure that the edges align perfectly. Press them together firmly. If glue squeezes out of the sides, wipe it up with a damp paper towel. If a lot of glue squeezed out, use less glue on the next steps. If no glue squeezed out, use a little more glue in the future.

Step 2: The Connecting Rod

New Parts:



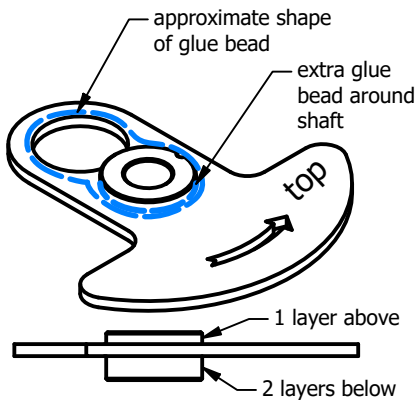
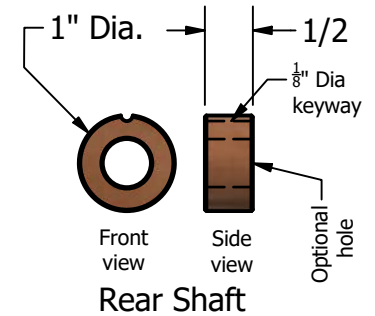
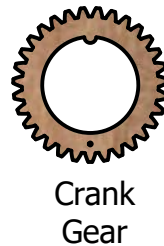
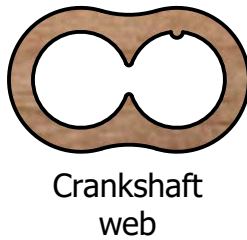
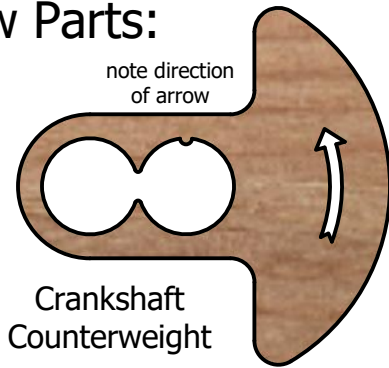
The outer rods will have one side that is better than the other. The not-so-good sides should face the inner rods. Temporarily set the inner rod over the outer rod as shown on the left, and draw a light pencil line on the outer rod where the inner rod ends. This will help you not to glue in the wrong place. Make a light glue bead on the outer rod, stopping before you reach the pencil line you drew. Assemble the connecting rod like you assembled the piston, making sure to line everything up. The small holes in the rod are to help line them up. You can use small peices of 1/8" dowel rod in these holes to help with alignment. If you like, you can glue these peices in place as part of the part. However, I personally choose to remove them, so I make sure they aren't glued in place.



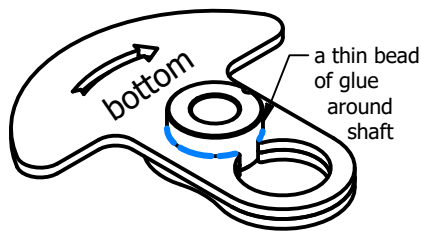
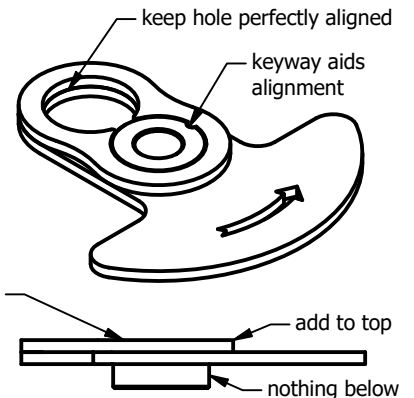
Step 3: The Crankshaft (Rear)

In most four stroke engines, the crank is usually all one part, and the rod comes apart to attach it. In our model, we make the crank in two parts, and glue it together over the rod. This is similar to how most two stroke engines go together in real life, and works well for plywood.

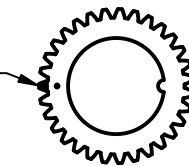
New Parts:



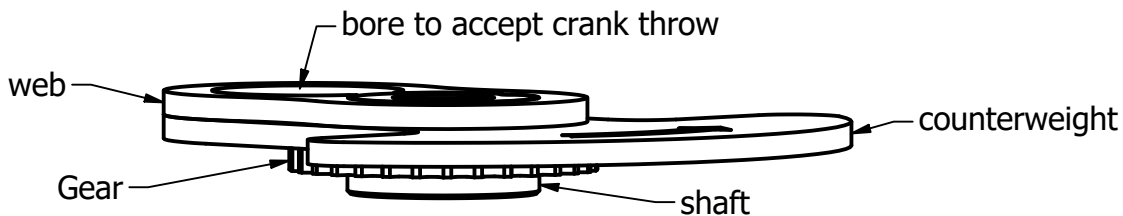
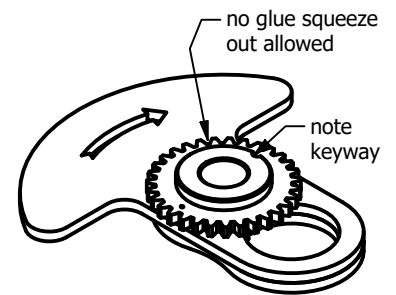
Position the rear shaft in the crankshaft counterweight part as shown. Make sure that the arrow is pointing the proper direction, and that the shaft is straight up and down. Add a medium bead of glue around the base of the shaft, and a light bead of glue where the crankshaft web will go. Push the crankshaft web down onto the top of the assembly. See figures to the left and right. Make sure that no glue squeezes out into the other hole in the assembly. Also make sure that the top of the shaft is level with the top of the crankshaft web, or even slightly below it.



Use a pencil or marker to color both sides of the tooth next to the dot on the crank gear.

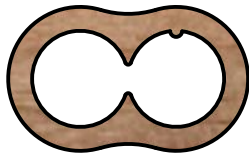


Turn the assembly over onto its back, and lay a thin bead of glue around the bottom of the shaft. Line up the keyway with the shaft, and slide the gear over the shaft. Bed it into the glue. Make sure that no glue squeezes out to interfere with the gear teeth. The shaft should stick out 1/8" beyond the edge of the gear.

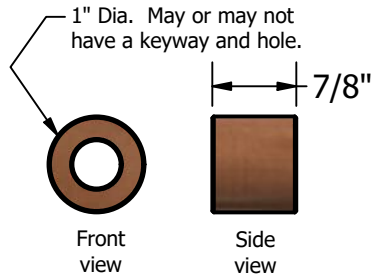


Step 4: The Crankshaft (Front)

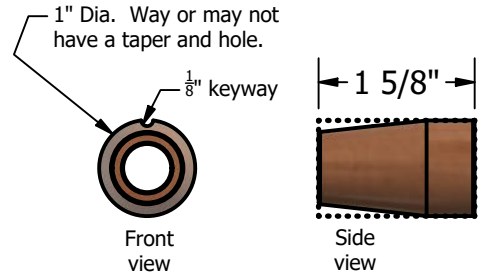
New Parts:



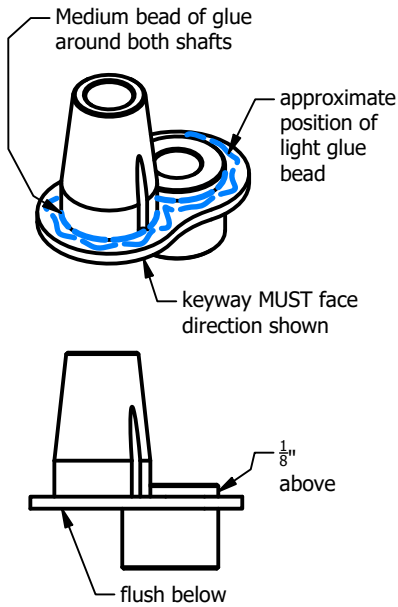
Crankshaft web x 2



Crankshaft throw

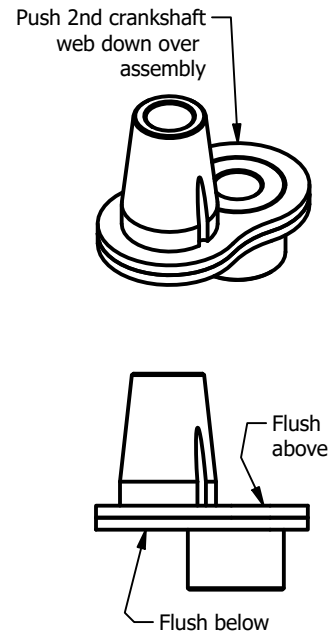


Forward shaft (PTO)



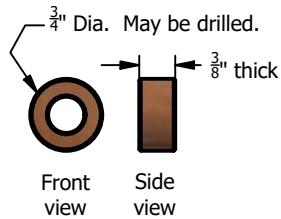
There is no counterweight on the forward half of the crankshaft on this model because it would make it hard to see the crank, so I have left it out. Otherwise, the assembly is similar. Take one of the crankshaft webs, and thread the forward shaft (sometimes called the Power Takeoff, or PTO shaft) over it, making sure to engage the keyway. It should end flush with the web. Slide the crank throw into the other side of the web, extending it 1/8" past the crank web. Make sure both shafts are straight in their sockets. Place a light bead of glue on the crank web and a medium bead of glue around each shaft, then add the second crank web. Make sure that both sides are now flush, and the shafts are straight. Allow the glue to dry.

This is a good time to see why this is called a crankshaft. Notice that if you hold one shaft, you can spin the other shaft like it is a crank!



Step 5: Rotating Assembly (A)

New Part:

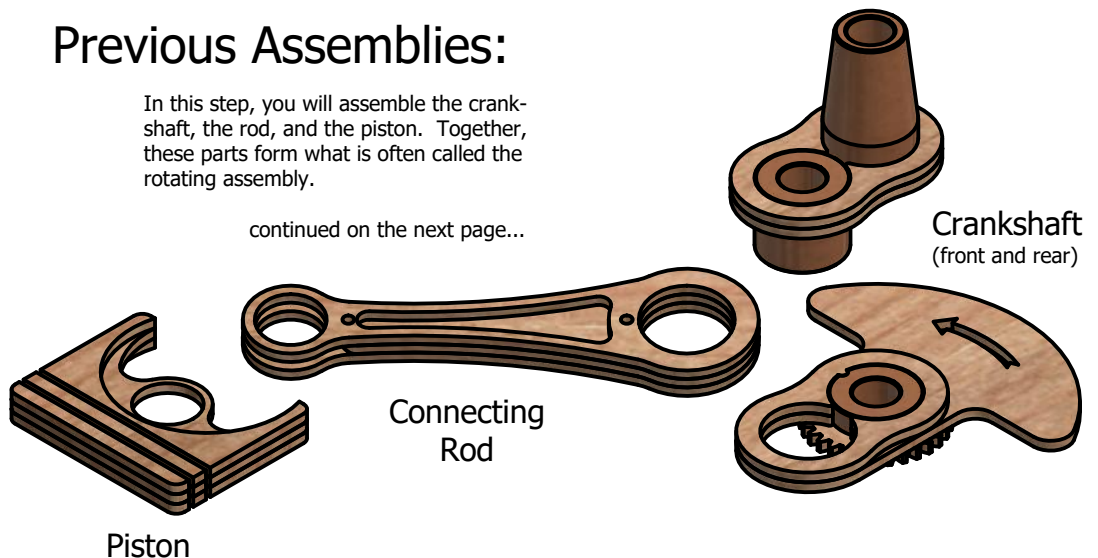


Wrist Pin

Previous Assemblies:

In this step, you will assemble the crankshaft, the rod, and the piston. Together, these parts form what is often called the rotating assembly.

continued on the next page...



Crankshaft (front and rear)

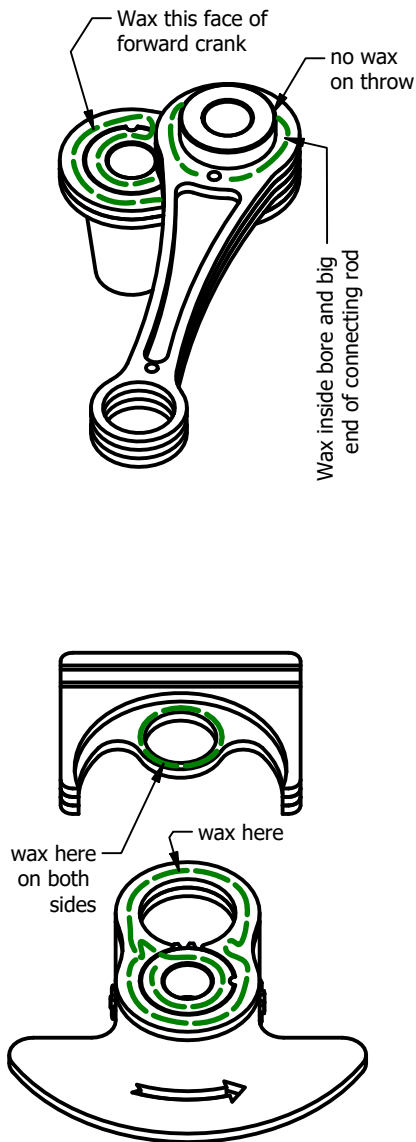
Connecting Rod

Piston

Step 5: Rotating Assembly (B)

Waxing Before Assembly

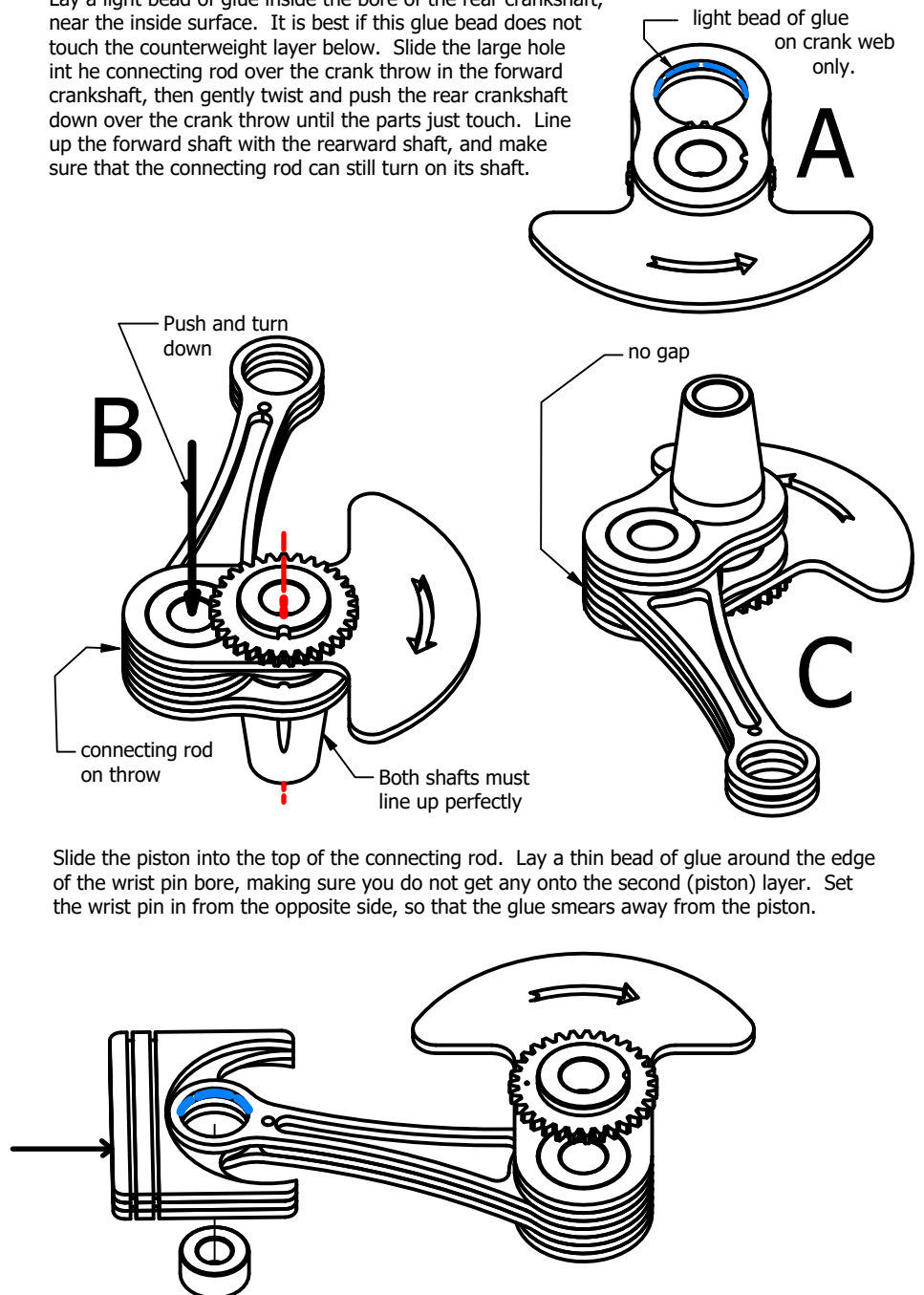
Before you put the rotating assembly together, decide which side of the piston and the connecting rod look the best. When you glue the assemblies together, the best sides should face forward. You should also decide if you are going to wax the assembly, which will make the engine turn a little easier. Wax the parts as shown below. If you don't want to use wax, just skip this part and the other waxing instructions later in the manual.



Gluing the Assembly

The two halves of the crankshaft need to be glued together over the connecting rod, which must spin freely on the crank throw. This means that the glue cannot be allowed to touch the connecting rod. Similarly, the wrist pin needs to be glued in its place in the connecting rod, but the piston must be able to pivot freely. This means that no glue can touch the layers of the piston. This means that this step must be done very carefully.

Lay a light bead of glue inside the bore of the rear crankshaft, near the inside surface. It is best if this glue bead does not touch the counterweight layer below. Slide the large hole into the connecting rod over the crank throw in the forward crankshaft, then gently twist and push the rear crankshaft down over the crank throw until the parts just touch. Line up the forward shaft with the rearward shaft, and make sure that the connecting rod can still turn on its shaft.

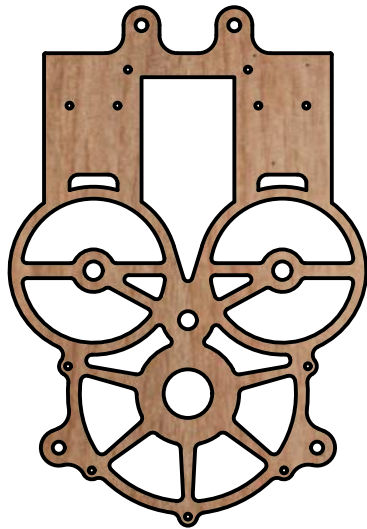


As the glue dries on the assembly, pivot the connecting rod and the piston every few minutes. This will ensure that any glue that accidentally got on the wrong parts can't lock the assembly.

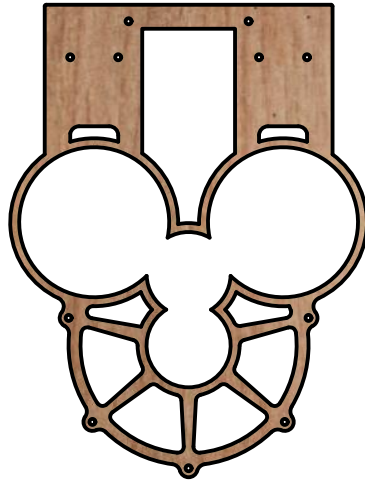
Step 6: Base and Cam Shafts

New Parts:

bases and gears shown 1/4" size

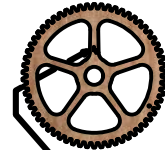


Rear Base



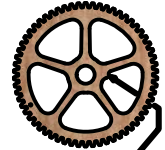
Front Base

Left
Cam Gear

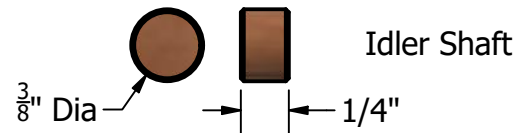
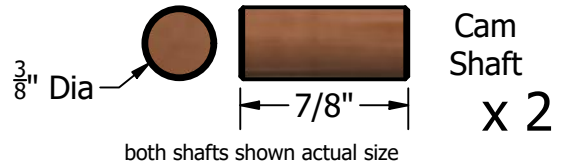


Note "L" on gear

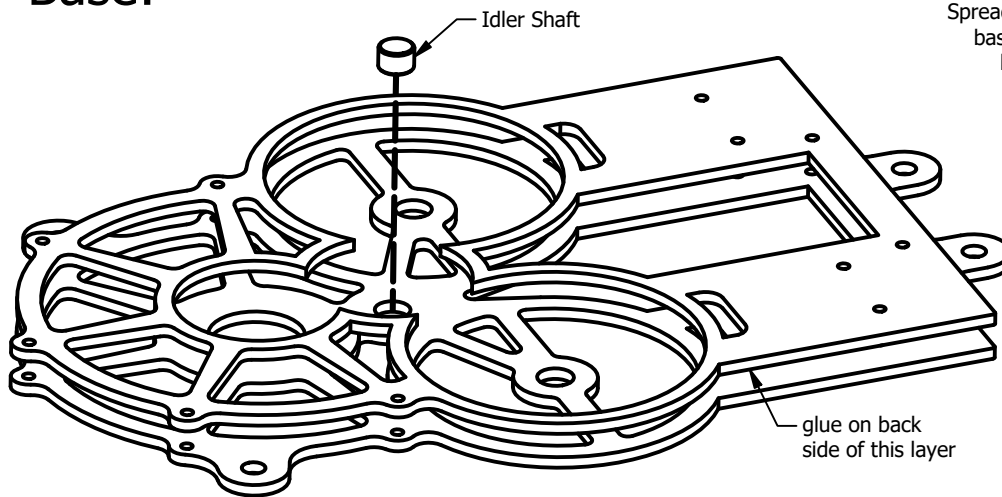
Right
Cam Gear



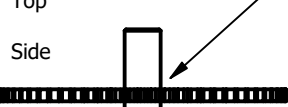
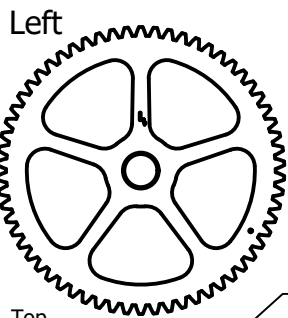
Note spike on gear



Base:



Spread glue lightly onto the back of the "front base" layer, and then glue it to the "rear base" layer. Use several 1/8" dowel pins to aid in alignment, but make sure that the pins are not glued in, so that the pins be removed before the next step. Glue the "Idler shaft" into the center socket, making sure that there is no glue squeeze out around the shaft, and that it does not extend more than 1/8" above the edge of the base. You can check this with a straight edge across the top of the "front base" layer.

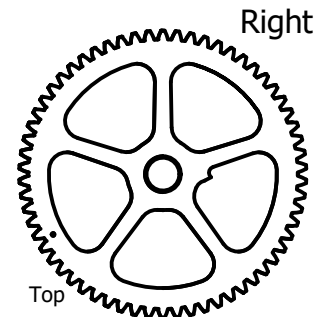


glued in hole. no glue allowed to squeeze out on either side.

shaft extends 1/8" (one layer) below

Cam Shafts:

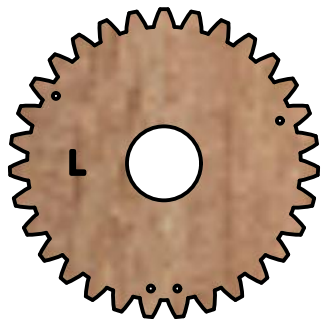
A real engine would have one cam shaft on the engine with two cams on it. This would be hard to see, so this model has two separate shafts, each operating one cam. Set the cam gears face up (look at the drawing carefully, and pay attention to the dot and the markings on the gears.) Lightly glue the gear bores, and push the cam shafts into the bores until they extend 1/8" (one layer of plywood) past the bottom of the gears. Wipe any glue away from the upper and lower surfaces of the shaft, and check to make sure that the shafts are square with the gear surfaces. Set them aside to dry.



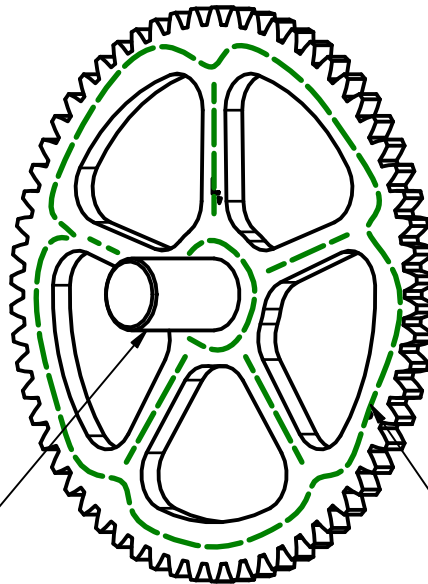
shaft extends 1/8" (one layer) below

Step 7: Fit Timing Gears

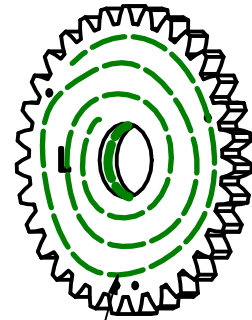
New Parts:



Idler Gear
(shown full size)



no wax on shaft



Wax both sides of timing gear. Also wax inside of hole (bore).

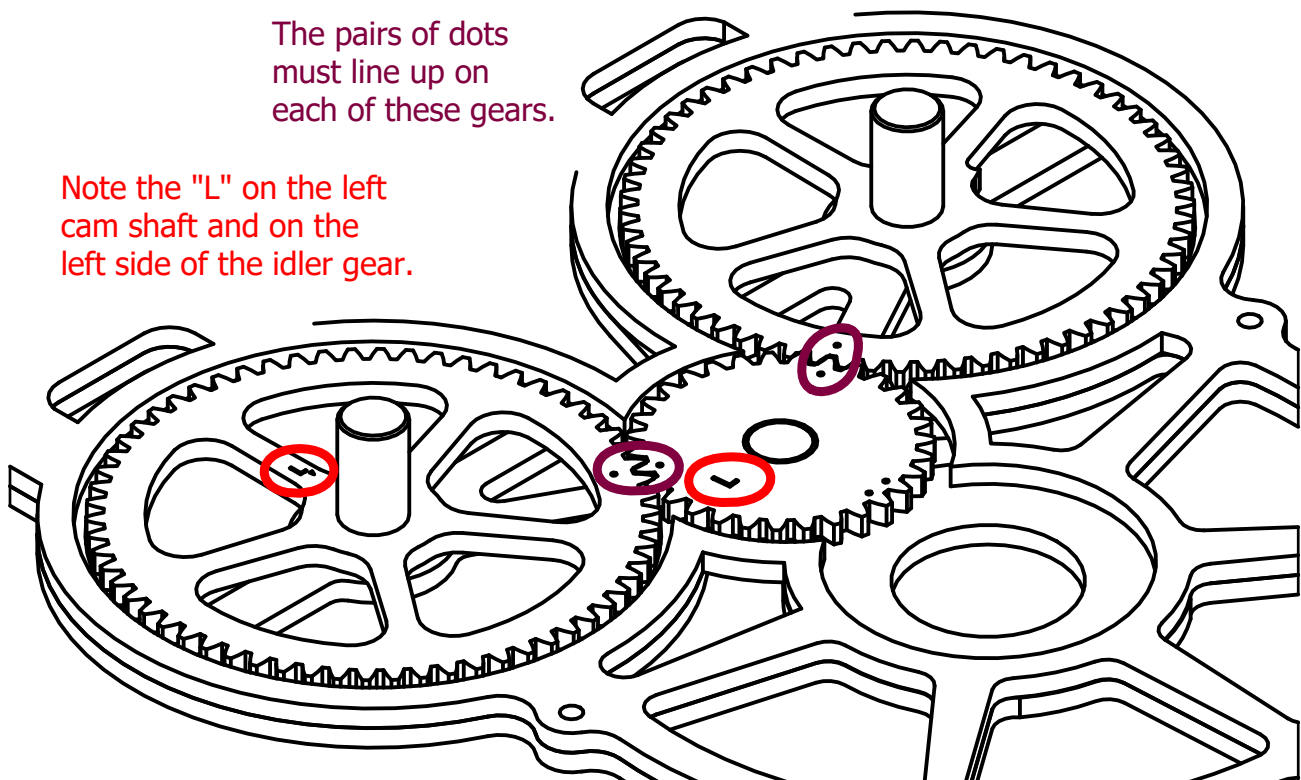
Wax both sides of both cam gears

The timing gears must mesh exactly in the right position with the other timing gears in the engine, or the engine would not be able to run. On real engines, every gear that must fit the exact tooth of another gear is marked. Some are marked by coloring and some are marked by a tiny bevel cut on one tooth. Many are marked with dots, like the ones in this engine kit. You cannot assemble an engine without knowing where each tooth lines up, and that is why we have instruction manuals.

Study the diagram below. Place the two cam shafts into their sockets, being sure the shafts face forward and the "L" is visible on the left cam gear. Rotate the cam gears until the dots are about the right position as shown in the circles, and then add the idler gear. Make small adjustments so that the marked teeth (dots) line up with the other marked teeth.

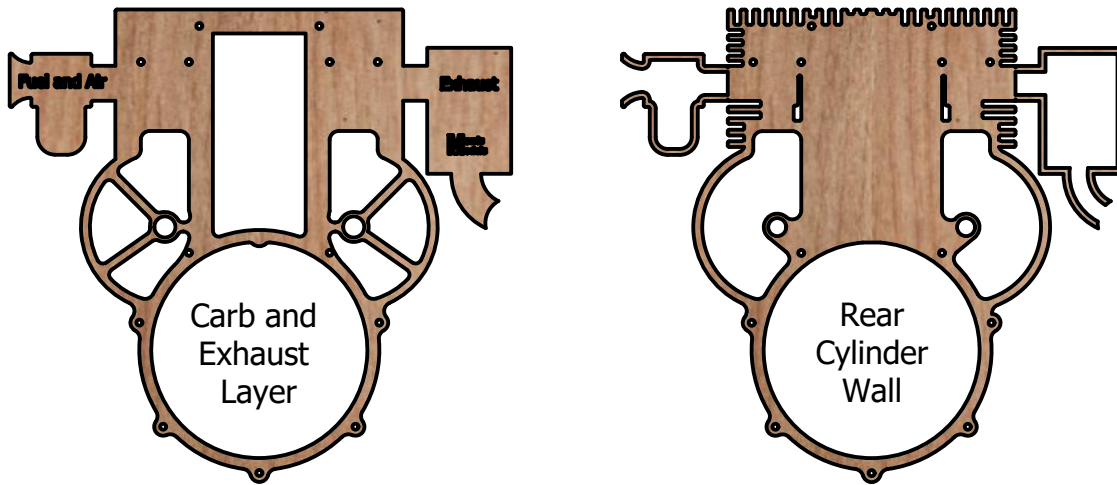
The pairs of dots must line up on each of these gears.

Note the "L" on the left cam shaft and on the left side of the idler gear.

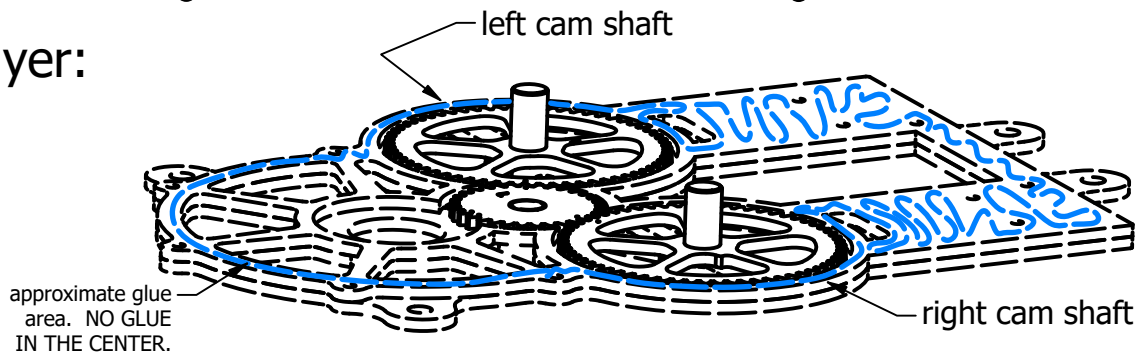


Step 8: Continue the Case

New Parts:



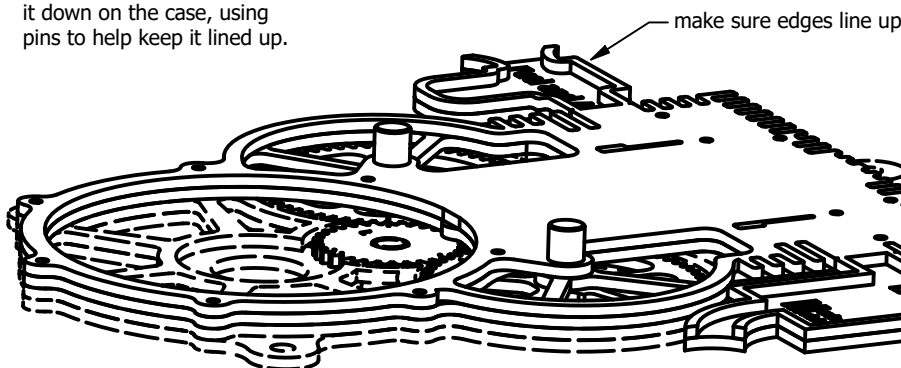
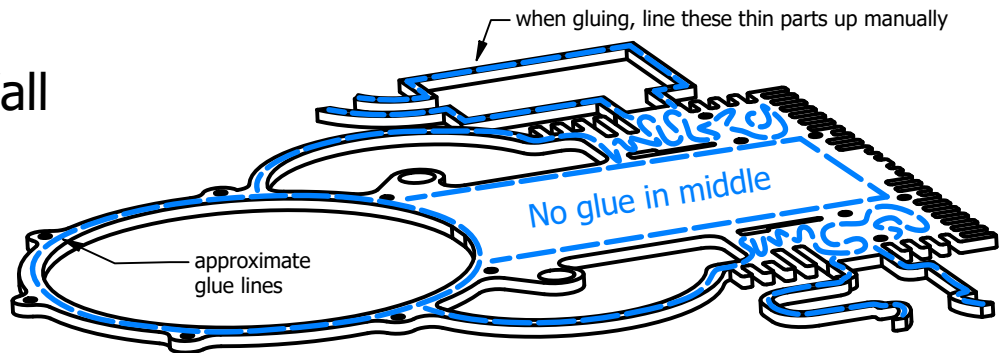
Glue Layer:



Lay down a thin bead of glue around the perimeter of the case and on the rectangular blocks on the top as shown in the diagram above. Set the carb and exhaust layer over the assembly, and press it down into the glue (not shown). Use pins to keep it lined up.

Rear Cylinder Wall
(turn upside down)

After gluing down the carb and exhaust layer, turn the rear cylinder wall layer upside down. Apply a thin bead of glue as shown, and put a tiny dab of glue on the end of each fin (not shown). Turn the layer over and glue it down on the case, using pins to help keep it lined up.

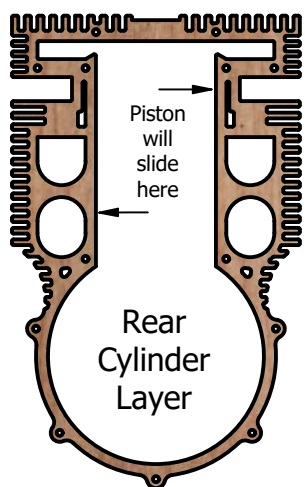


Completed Step

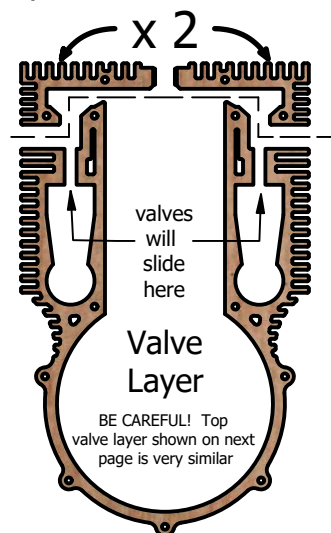
New parts added on this page are shown as solid lines. Parts added in previous steps are shown with dashed lines. Make sure that the gears can spin before moving on to the next step.

Step 9: Begin Cylinder Walls

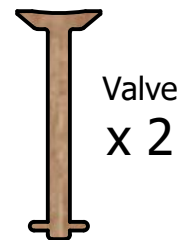
New Parts:



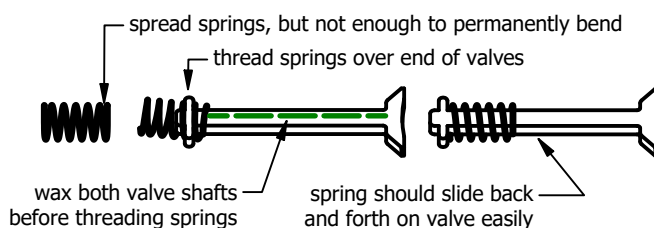
Cylinder Head Corners



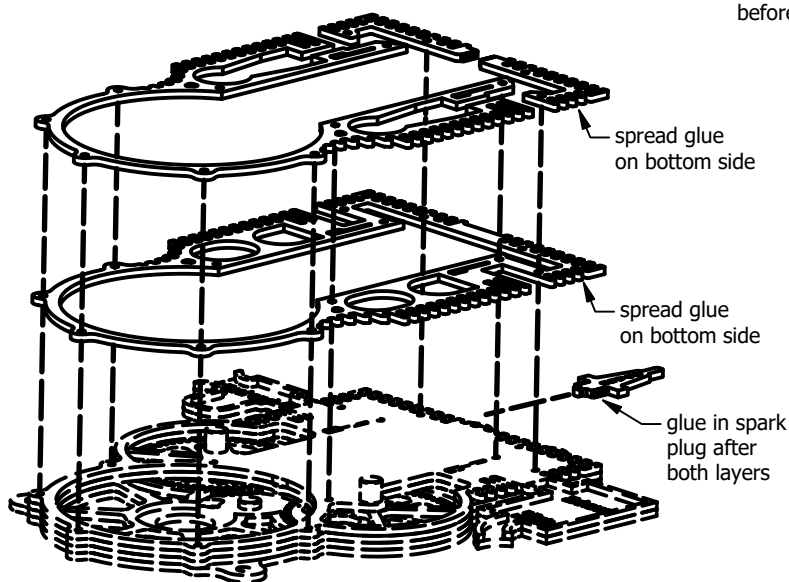
Spark Plug



Put Springs on Valves



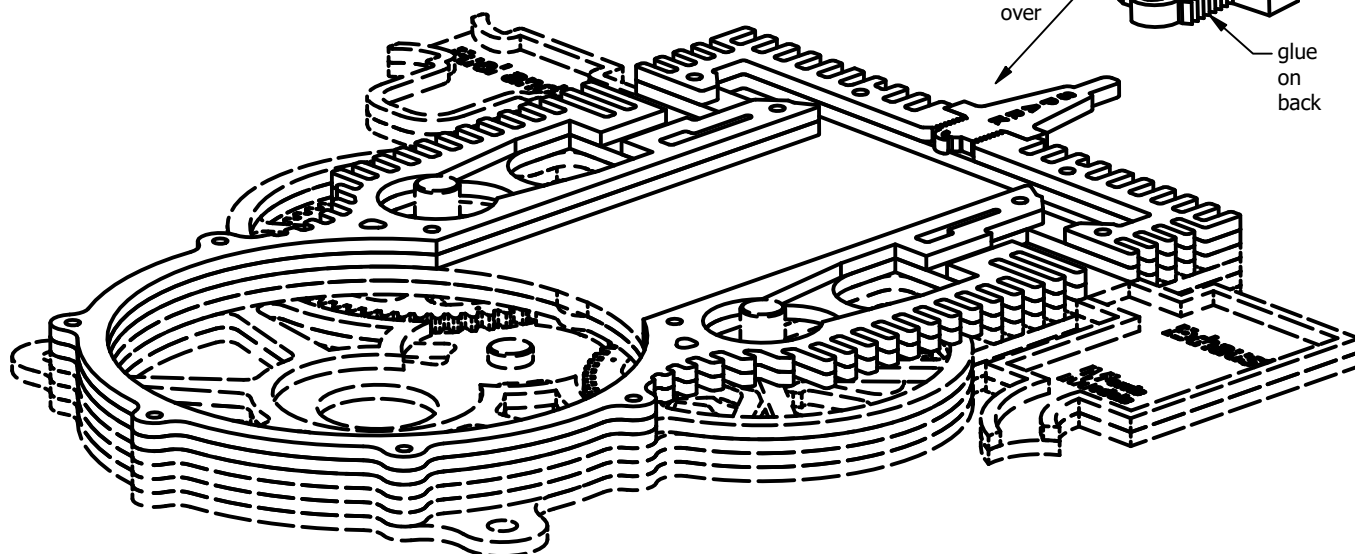
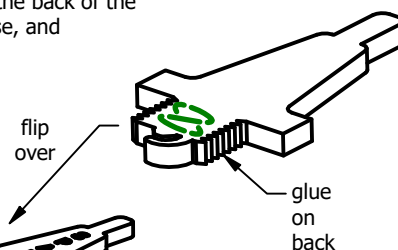
Add the next two layers



Spread a thin bead of glue on the back side of the rear cylinder layer. Press it in place over the engine assembly, again using guide pins to help line it up.

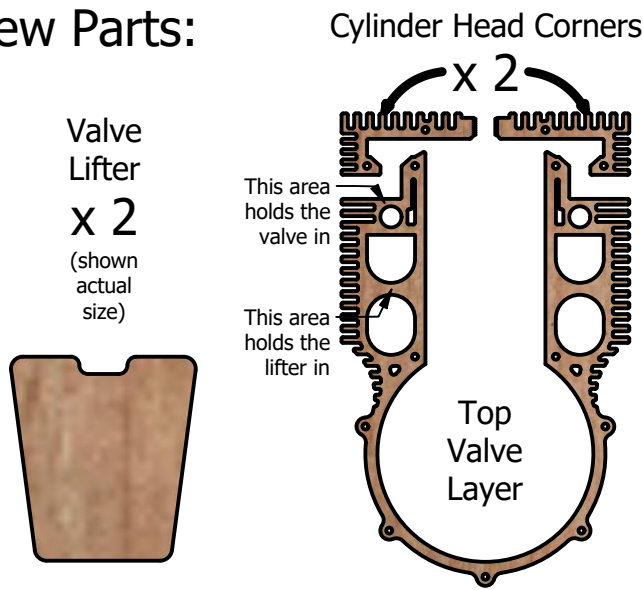
Spread a thin layer of glue over the big part of the valve layer. Press it down into place over the engine assembly, using those same pins. Then spread a thin layer of glue over the backs of the two cylinder head corners, and glue them onto the assembly. Wipe up any glue squeeze out, particularly where the valves go and where the piston goes.

Apply glue to the back of the spark plug base, and glue it into its socket.



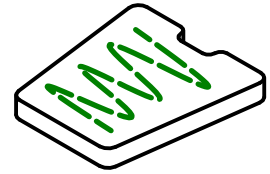
Step 10: Finish Cylinder Walls

New Parts:



1st

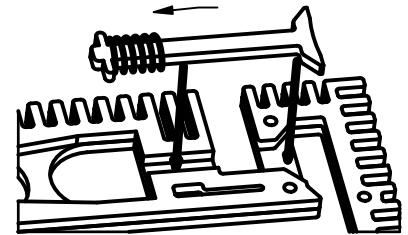
Wax both sides of both valve lifters.



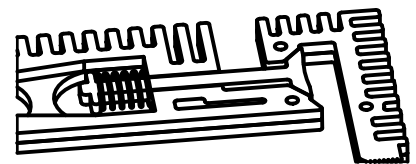
2nd

Squeeze valve spring and insert valve into location, held by valve spring. Do both sides.

A

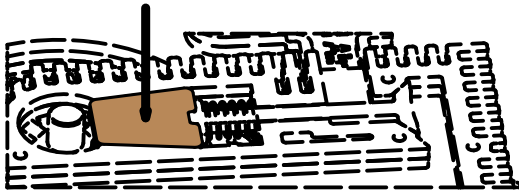


B

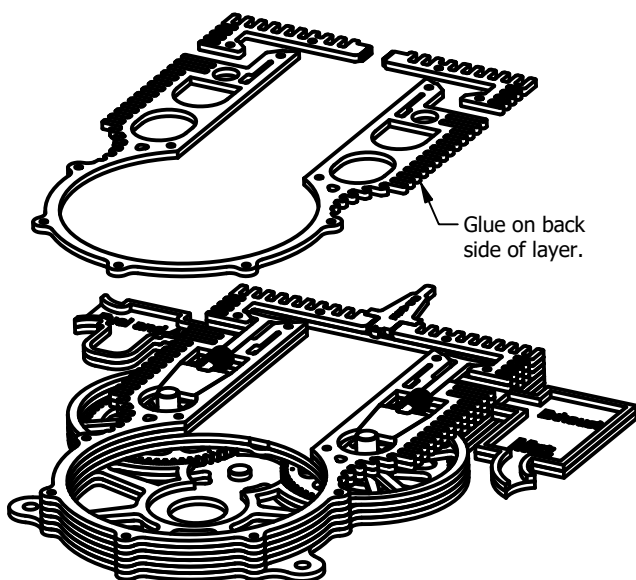


3rd

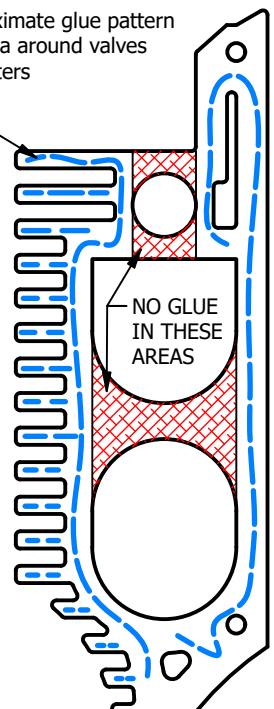
Insert valve lifters into sockets below valves. Make sure not to dislodge valves. Do both sides.



Last



Approximate glue pattern for area around valves and lifters

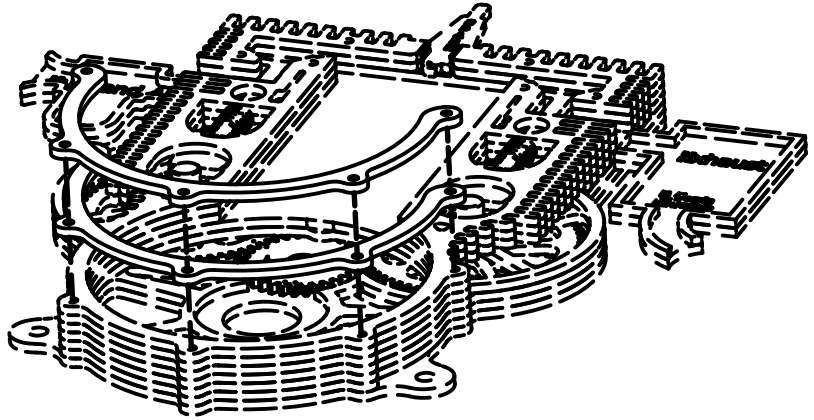
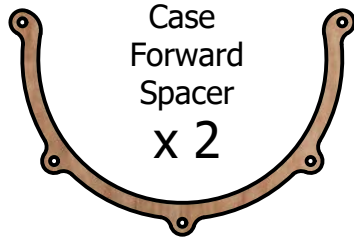


Spread a thin bead of glue glue on the back side of the top valve layer and cylinder head corners. Be very careful not to glue the valves and lifters, which must be free to slide. Avoid the area shown on the right, and use very little glue as you get near these layers.

Attach the top valve layer and corners down over the model, using alignment pins to help you. While pressing down on the layer, check to see that the valves and lifters can move upwards when you push on the bottom of the lifter, and will spring back into place when you let go of the lifter. If they cannot do this, take the layer off, and figure out what is holding them.

Step 11: Prepare Case

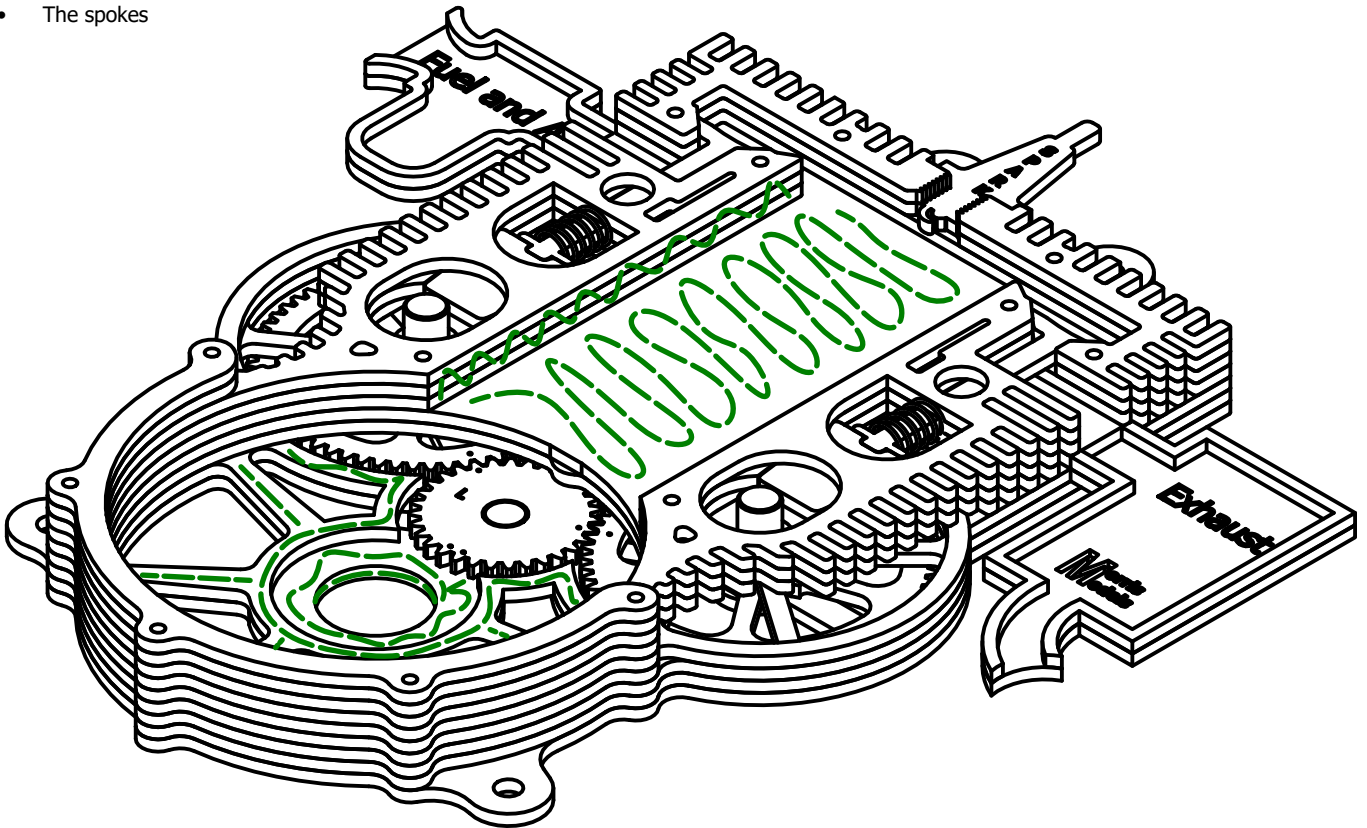
New Parts:



Spread a thin layer of glue on the bottom of each forward case spacer, and add them to the engine in the position shown. Use alignment pins.

Wax the engine as shown below, making sure to include:

- both sides of the cylinder walls
- the back of the cylinder
- The bore at the back of the engine
- The area around the bore
- The spokes

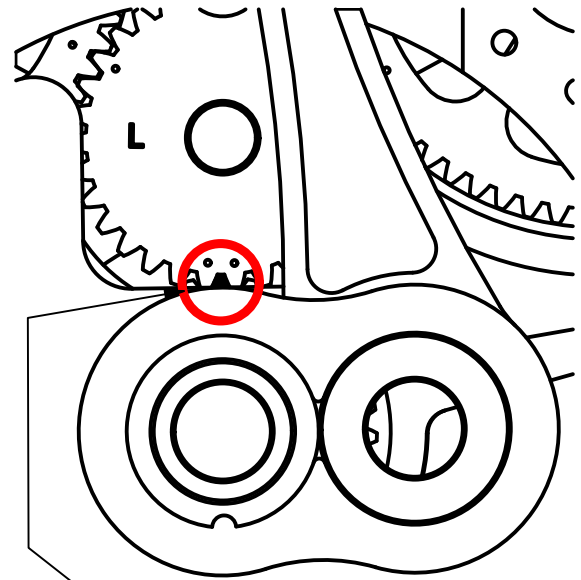


Step 12: Fit Rotating Assembly

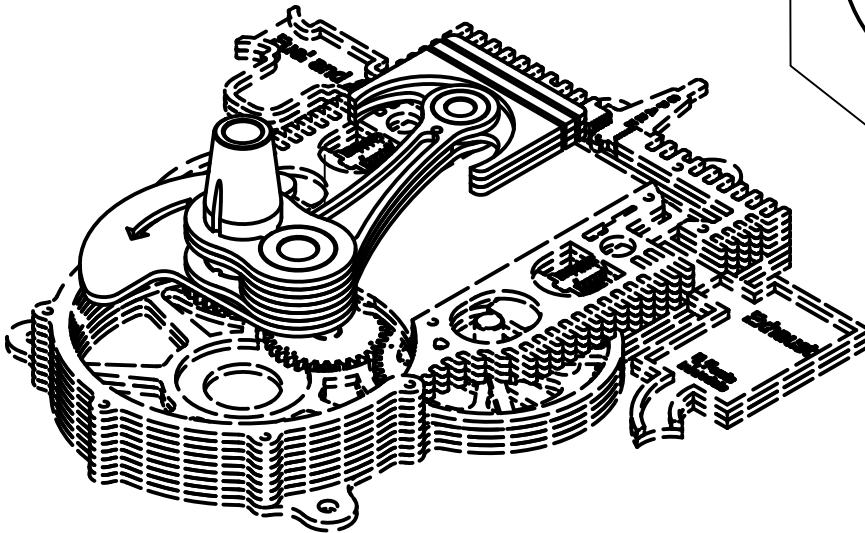
Locate the rotating assembly you built back in in step 5. Pull it into the approximate shape shown in the drawing below, and carefully fit the rear shaft into the socket in the center of the engine. The teeth of the crank gear will engage with the teeth of the idler gear. Make sure that the set of two dots on the idler gear surround the single tooth you colored on the crank gear as shown in the circle on the right.

Work the piston down into its cylinder as well as the crankshaft down into its bore. You can rotate the crankshaft back and forth and see the motion of the piston in the cylinder. It should move smoothly without catching on anything. If it binds and catches, remove the rotating assembly and fix whatever is catching it as it spins.

Check to make sure your gears line up correctly one last time before going on.



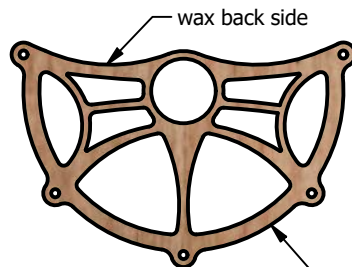
The 2 dots on the idler gear go on each side of the tooth you colored back in step 3 on the crank gear.



Step 13: Close the Case

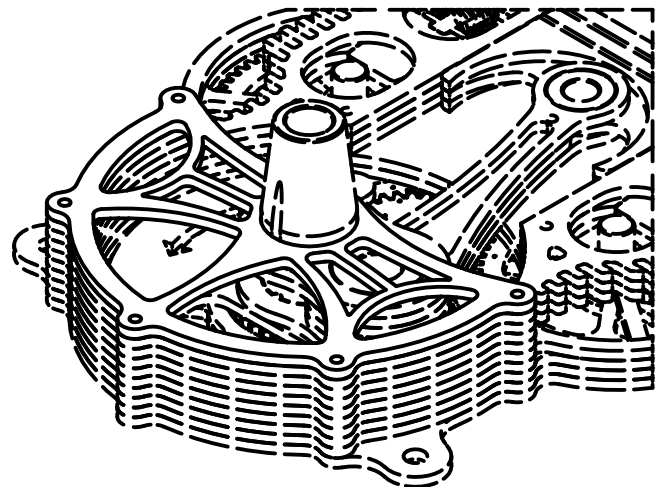
New Part:

Front Case Support



Wax the back of the front case support, including the bore and the spokes. Do not wax the edge circle.

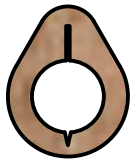
Now lay a thin bead of glue around the outside edge of the back of the case front (the part you didn't wax), and glue it down over the top of the case as shown in the drawing. You should use alignment pins to help you line up the case front, of course.



Step 14: Set the Cams

New Parts:

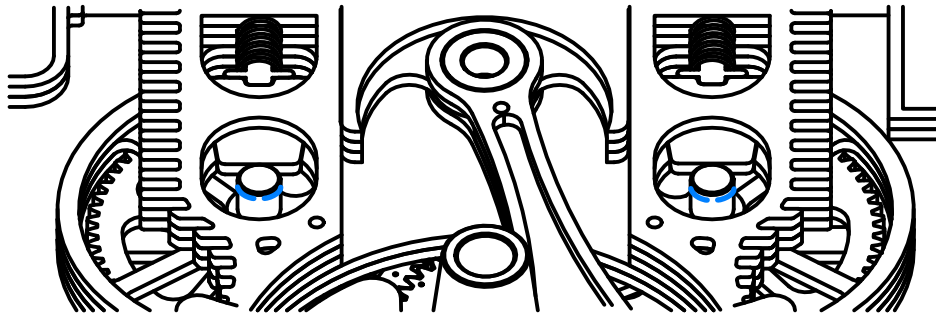
Cams
x 2



(shown
full
size)

Make sure that the timing marks are lined up before going on. Lay a thin bead of glue around the top of one cam shaft (both are shown below, but you should do one at a time).

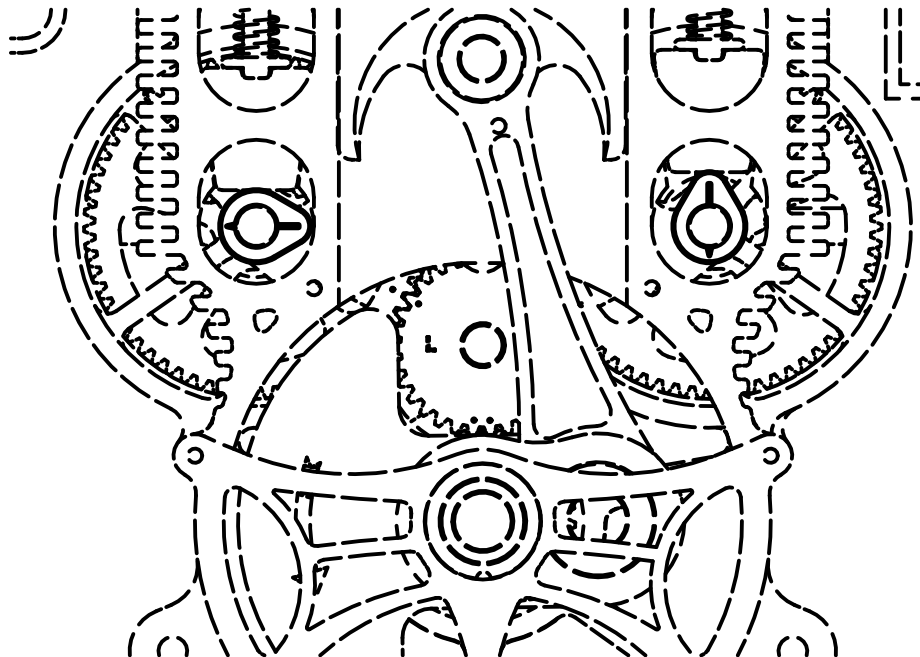
Once the glue is in place, use one finger or a screwdriver to slide the valve lifter up towards the top of the engine. This will make enough room to slide the cam into position. Hold it up while you fit the cam, as described below.



Now, twist and slide one of the cams down over the shaft you just glued. Pay attention to the direction the cam should face, as shown in the drawing below. The right cam should face straight upright. The left cam should face straight towards the right. Both cams should be pushed onto the shaft until they are at the same level as the valve lifters. No glue should touch anything except the cam and the shaft.

Congratulations. You have just completed this model. Allow them to dry before turning the engine.

Your engine may be a little difficult to turn at first, but if you have followed all of the directions, it should work well. The more you spin it, the better it will turn.



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