

2 Cylinder Slidevalve Steam Engine

By Thor Hansen

After making a slide valve engine that I managed to get running I decided to try and make a 2-cylinder version. Since the first one was a vertical steam engine, I made the 2-cylinder horizontal. The engine uses the same 16mm bore and 20mm stroke as the previous one, but with a different multi-throw crankshaft with the two crank pins at 90 deg. Many thanks to Graham Meek for his advice.

Materials

I had acquired a 32mm dia. piece of leaded gunmetal and used that to make the cylinders. I bought a few pieces of brass and some rods of free-cutting stainless steel; the rest was mild steel from my box of scrap.

Crankshaft

The Crankshaft was made from 8mm dia. bright mild steel rod and four pieces of 8mm thick black mild steel plate for the webs. I used a hacksaw to get the pieces roughly to dimension and glued two web pieces together to make a pair and drilled and reamed a 6mm and a 5mm hole 10mm apart.

I made a fixture to hold the web pair in the lathe – see right photo. The pair of webs could then be turned to an outside diameter of 33mm.



The work was then transferred to my milling machine and mounted in a 4-jaw chuck on the rotary table so I could mill the webs to final dimensions – left photo. Below is the result. The second pair of webs were made the same way.



Before using heat to split the two parts I turned the side of the webs down slightly, about 0.25mm except around the holes for the crankshaft and crankpin. This is so most of the web will clear the bearing or big end of the conrod. The holes in the web were opened up to 7.8mm and reamed to 8mm.

The webs were glued to the crankpins and Crankshaft using anaerobic glue. I started by gluing the crankpins to the web. The Crankshaft was put through the holes without any glue while the glue on the crankpins cured. The crankshaft rested on a couple of V-blocks while the glue cured.

Since the crankpins must be at 90 deg. to each other to make the engine self-starting I made a spacer that would just slide under the crankshaft while it was resting on the V-blocks. This spacer will make sure that the crankpin will be resting at the same height as the crankshaft – right photo.

I also made a small square to make sure that the other crankpin will be at 90 deg. to the crankpin resting on the spacer.

After the glue had cured I drilled 1.6mm holes through the webs and



Crankshaft and inserted some mild steel pins together with a drop of anaerobic glue. The Crankpins were "pinned" in the same way. When the glue had cured I used my Dremel clone to grind the pins flush – see photo above.

After the glue had cured and the pins ground flush, I mounted the Crankshaft in the ER collet chuck in the lathe and supported the other end with a revolving centre and trued up the webs. I used a boring tool to be able to turn the side of the webs.

Bedplate

The Bedplate (or base) was made from a mild steel profile I found in a skip. After a bit of hacksawing I had three pieces I could weld together. Since my welding skills could do with some improvement I had to use an angle grinder and then a file and some elbow grease to get to this:

The Bedplate was left like this until I had made the Bearing Blocks.



Bearing Blocks

The bearing in the middle of the Crankshaft has to be split, so I started with that. The other two bearings were made the same way I made bearings for the vertical steam engine.

I started with a piece of 8mm thick steel that I milled square and milled each side so it ended up about 7.5mm thick. I used a hacksaw to cut the piece in two about 0.5mm above the centre line of the Crankshaft. The largest piece was milled flat on the top just at the Crankshaft centre height. I then milled a 11mm wide slot to a depth of 5.5mm. Then I used a 3mm slot drill to mill a slot at the bottom of the wider slot. For the bearing I used two pieces of brass left over from another project. The brass was milled so it could just be pressed into the wide slot. On the bottom part of the brass I milled a small ridge that would fit into the 3mm wide slot in the Bearing Block – right photo. The photo also show the bottom part of the split bearing. The brass part is a light press fit, I also used a drop of anaerobic glue before pressing the brass in place.



The work was then transferred to the lathe. I used two M3 cheese head screws to hold the two parts of the bearing block together, and another two screws to clamp the bearing block to the jig – see right photo.

I drilled a pilot hole first but the drill wobbled a little so I used a slightly larger diameter end mill to get the hole true. After boring to just under 8mm the hole was reamed to 8mm.

The other two "outer" bearings doesn't have to be split so they were made the same way as those I made for the vertical steam engine. I used 6mm thick steel and machined the work to dimensions. The two blocks were mounted to the same jig as the split bearing, to make sure all three holes for the Crankshaft ended up at the same height. The holes in the two blocks were bored to just under 10mm so the pieces of 10mm OD brass tube was a press fit in the hole. The brass bushes were then reamed to 8mm. The brass bushes were made over length, and the blocks were mounted again on the faceplate jig and

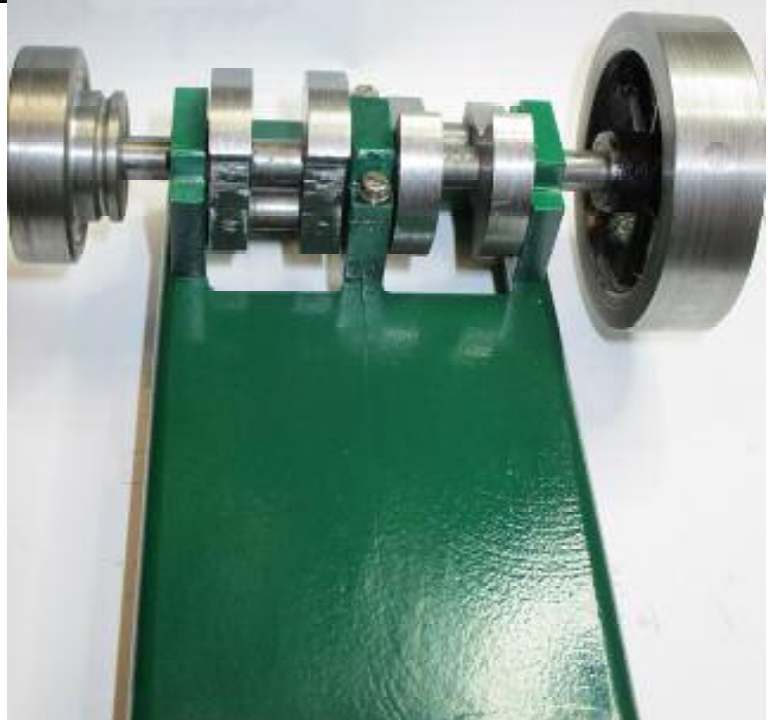


the bushes turned so just about 0.25mm protruded on each side. Since I did something similar when making the webs there should be about 0.5mm clearance between the webs and the bearing blocks.

Next, the top of the Bedplate was milled flat and the bearings were mounted on the Crankshaft and the assembly placed on the Bedplate and the positions of the bearings marked out. In the Bedplate there needs to be two holes for the webs. I drilled a few holes and used a hacksaw to cut out most of the material. Then the Bedplate was mounted on the milling table and the two holes milled to the marked out outline – right photo.



I also made a flywheel and a small pulley. I used a M4 setscrew to secure the pulley. For this engine the large flywheel is probably not necessary, and I will probably only use the pulley. But I guess the flywheel can be used on another engine. I drilled through the Bedplate using an oversize drill and mounted the bearing blocks using M3 cheese-head screws. The oversize holes in the Bedplate made it possible to make small adjustments to the bearing blocks so the Crankshaft rotated freely – right photo.



Trunk Guide

I fabricated the Trunk Guide for the Cross-head from some 3x30mm brass flat and 18mm OD, 16mm ID brass tube. I cut two square pieces from the brass flat and two pieces just over 37mm long from the brass tube. The square brass pieces were mounted in the 4-jaw and a hole drilled through the centre, the hole was opened up so the brass tube could just pass through.

The flat and the tube were silver (hard) soldered and pickled in citric acid. The corners of the brass flat were sawed off and the work mounted in an ER collet in the lathe and the octagonal piece turned to a diameter of about 29mm and then faced – right photo.



The next operation was to mill away the sides to make the apertures on each side of the Trunk Guide, I used an 8mm end mill.



Bottom Cylinder Cover

The Bottom Cylinder Cover was fabricated from pieces of brass flats and a short piece of 10mm diameter brass rod. I also used a thin brass nail to try to prevent the pieces from moving during silver soldering. It worked well on one, not quite so well on the other – right photo. I also made a steel ring with 29mm outer diameter and a 16mm reamed hole that was used to



test the fit of the spigot that will enter the bottom of the Cylinder. I also plan to drill 6 holes spaced 60 deg. apart on a 24mm PCD so I can use the ring as a drill jig.

I decided to mount the work in a 4-jaw independent chuck on my rotary table and mill the spigot, that worked fairly well.

I didn't have any suitable parallels so I simply used a couple of 10mm end mills, when I measured they were 9.99mm wherever I measured the diameter – see left photo that also shows the ring used to test the diameters.

While the cover was still on the rotary table I used the steel ring and drilled six 3mm holes spaced 60 deg. apart on a 24mm PCD.

The rest of the work on the Bottom Covers will have to wait until I have made the Cylinders.

Cylinders

The cylinders were made from a piece of leaded gunmetal just over 32mm diameter, 34 or 36mm would have been better.

To be able to hold the cylinders while machining the outside I made a flanged mandrel 16mm diameter and threaded on the other end and made a suitable nut – see right photo, it also show the ring used as a drill jig for the screws holding the covers. The flange has six 3mm holes spaced 60 deg. apart on a 24mm PCD, just like the ring. This way the cylinder can be clamped on the mandrel while machining the outside.

I used a hacksaw to cut the gunmetal to get two pieces just over finished length and then faced the cut ends. The ends were marked out, the centre of the bore is just over 2mm from the centre of the gunmetal rod so I could get a port face – right photo. I will probably have to solder a portblock onto the cylinder.

The cylinder blank was mounted in the 4-jaw and adjusted so the marked out centre of the bore was running true.

I used a centre drill to get a true start and drilled a pilot hole through the work. I had stoned the edge of a few twist drills to prevent them from snatching in brass and used them to open up the hole in steps to 13mm – right photo. The drills worked well.

I then used a boring bar to bore the drilled hole out to 15.8mm, I then mounted my ER-32 chuck in the lathe tailstock and used it to clamp the 16mm reamer. This worked very well, better than the drill chuck I had used before.

The front was faced and the diameter turned down to just under 29mm for a length of just over 2mm, this was done so the machined end of the Bottom Cylinder Cover would fit.



The Bottom Cylinder Cover was then fitted and oriented in the correct way with respect to the cylinder port face and I used my Dremel clone rotary tool to drill a 2.5mm hole in the cylinder end – right photo. I tapped the 2.5mm hole M3 and used a cheese head screw to hold the cover in place when drilling (and then tapping) the next hole. With three holes drilled and tapped I could secure the cover to the cylinder and face the spigot of the gland and drill and ream the hole for the Piston Rod.



The outer end of this hole was centre drilled. The cheese head screw were removed and replaced with short pieces of M3 threaded rod, so short that the only protruded half-way into the cylinder cover. These short threaded rods will make the cover rotate with the cylinder and a centre in the tailstock will push the cover against the cylinder – right photo. This way I could turn the spigot for the Trunk Guide and be sure that it was concentric with the cylinder bore.



The next job was to try and mill the outside of the cylinders to make them look a bit like they were cast.

I mounted one cylinder on the mandrel I had made earlier and used some M3 cheese head screws to clamp the cylinder to the mandrel flange. A ring and a nut at the other end was also used to clamp the cylinder.

The mandrel was mounted in my home made dividing head and the other end supported by a tailstock. I used a 5mm end mill to mill the outside while rotating the work with the dividing head.



The milling worked but for the first cylinder I just

counted revolutions of the handle and my old brain managed to loose count.

The port face part was the last part to be milled using a 30mm carbide tipped face mill – right photo.

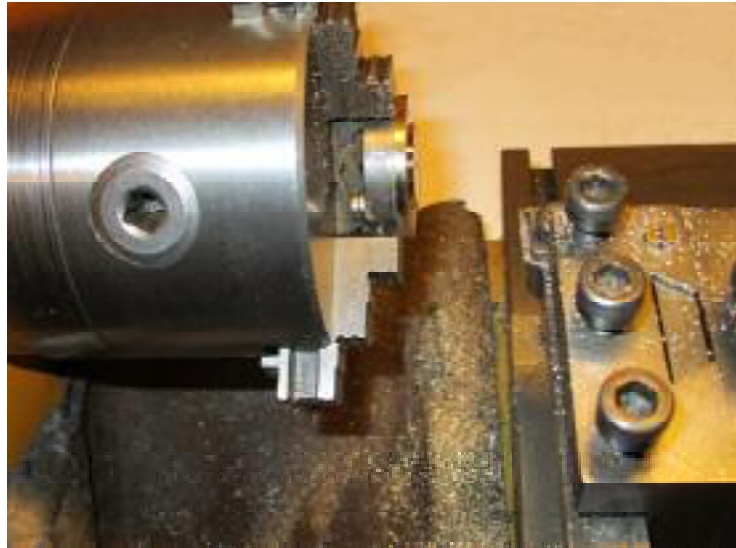
For the second cylinder I milled the port face first and then used a 5mm end mill to machine the rest of the outside, this procedure worked out better and was easier.

A friend of mine sand blasted the outside (except the cylinder ends and port faces), this made the cylinders look a bit more like castings. Later I soft soldered a portblock to the portface.



Top Cylinder Covers

The top covers were made from a piece of 3 x 30mm brass flat. I cut off two pieces 30mm long and marked out the centre with a small centre mark. I could then use a compass and mark out the cylinder bore and the outside diameter. I then used the ring I made earlier for marking out the bolt holes on the bottom cover and marked out three holes on the top covers. I drilled the holes 2.5mm and tapped them M3. Using the ring I could now clamp the work to the ring, cut off the four corners with a small hacksaw and mount the whole in the 3-jaw and turn the 1mm spigot that will fit into the cylinder – right photo.



Piston & Piston Rod

The pistons and piston rods were made from stainless steel. I used 316 for the pistons since I had a suitable piece and 303 free-cutting stainless steel for the rods. The 316 rod was a sliding fit in the cylinders so I just mounted it in the 4-jaw and used a dial indicator to centre it. Then the rod was faced and a centre drill used to start the hole for the piston rod. I used a 2.5mm drill and drilled to a depth just over the length of the piston. Then a 3mm drill to a depth of 5mm. The 2.5mm part of the hole was



tapped M3. A parting off tool was used to turn the groove for the packing, and the piston was then parted off. I also drilled two shallow 2mm holes at the top of the piston, I can the use a small pin spanner when tightening the piston onto its rod.

Crosshead

The crossheads were made from a piece of mild steel rod just over 16mm in diameter. I turned down one end to a sliding fit in the Trunk Guide and drilled an axial 2.5mm hole. Then I moved the work to the milling machine and mounted the steel rod in the chuck on my indexer.

I used a 10mm slot drill to mill each side – right photo – until there were 6.5mm material left in the middle. A 3mm hole were then drilled about 4mm from the end, and at 90 deg. to the previous hole.

The work was then returned to the lathe and the first crosshead parted off. The axial 2.5mm hole was tapped M3 and the other end rounded off a bit with a file. The process was then repeated for the second crosshead – right photo.



Conrod

I decided to fabricate the conrods from steel parts and use brass for the split big end bearing. I used a piece of 15mm diameter mild steel rod for the small end (with the fork), and a piece of 8mm x 18mm mild steel for the steel part of the big end, the rest if the big end were made from brass as I didn't have any suitable gunmetal.

I started with the *small end* part of the conrod. The work was mounted in the indexer – right photo – and one side milled flat. The work was turned 180 deg. and a similar flat milled to the same depth – to give a width of 8mm.

The work was turned 90 deg. and a new flat milled but less deep than the previous. The work



was again turned 180 deg. and a flat milled to a similar depth so that the spigot was just over 12mm wide in that direction. I then had an 8 x 12mm spigot about 20mm long.

I then milled a 6mm slot to a length of about 11 mm and then used an end mill to widen the slot to just over 6.5mm so it would fit over the narrow part of the crosshead. The work was turned 90 deg. in the indexer and a 2.5mm hole drilled about 4mm from the end. The hole was drilled through both the top and bottom part of the fork. The hole in the top part was tapped M3, the other was opened to 3mm. I made a small steel pin that was threaded M3 for a short length and fit through the holes.

The work was then transferred to the lathe and a 3.3mm hole drilled axially at the end of the forked part and tapped M4. The part with the M4 thread was turned down a bit and the work parted off. Then a file was used to round the end. Here's a photo of the small ends mounted on the crossheads. The piece of M4 threaded rod will be replaced by a 4mm diameter rod threaded M4 at each end.



The next job was to make the *big end*, I used a piece of 12mm square brass for the split bearing and a piece of 8mm thick mild steel for the part that will thread into the 4mm mild steel rod.

The 8mm thick steel was mounted in my 4-jaw about 8mm protruding from the jaws – see photo. The work was faced and a short spigot turned. A 3.3mm hole was drilled to a depth of about 7mm. I used a hacksaw to cut off a length just over 5mm, the work was then transferred to the milling machine and the sawed surface milled flat.



Next I used a small hacksaw to saw the 12mm square brass in two and mill the sawn surfaces flat – left photo.

The two brass pieces and the mild steel piece were glued together with anaerobic glue and the positions of the two 3mm holes were marked out and I used a 2.5mm drill to drill through all three parts. The 2.5mm holes in the mild steel part were tapped M3 – right photo.

Heating weakens the glue so after removing the mild steel part the 2.5mm holes in the brass parts were opened up to 3mm.



The two parts were held together with some M3 screws and the position of the 8mm hole was marked out and a pilot hole drilled. This hole was opened up to 7.8mm and then reamed to 8mm – right photo.



I then clamped a piece of 12mm mild steel rod in the lathe and turned a short spigot to a diameter just over 8mm so I could clamp the split bearing onto that part of the rod- photo above.

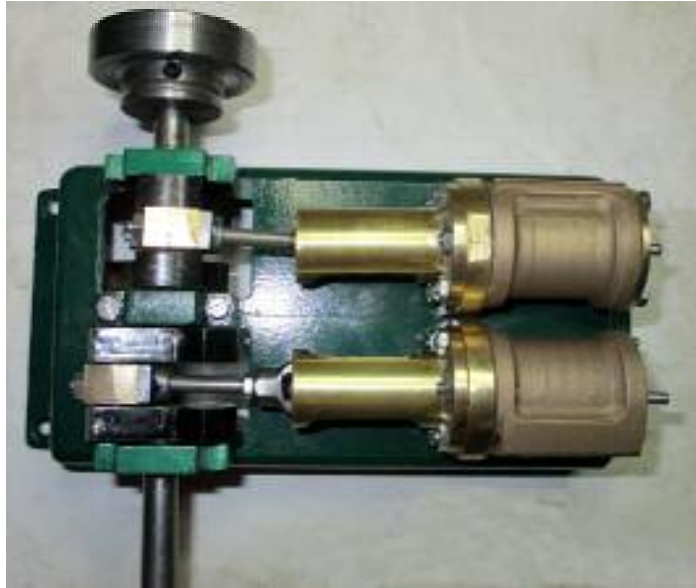
This way I could face each side of the split bearing to get the correct width and turn a 0.25mm protrusion around the 8mm hole. The



split bearing was test mounted on the crankpin and it moved smoothly.

The 4mm diameter rod connecting the small end and big end was cut to length and threaded M4 at each end using a tailstock dieholder. The thread closest to the small end was threaded over length so I could use a locknut.

The cylinders were placed on the Bedplate and their position marked out. I drilled 3mm holes in the Bedplate, two for each Bottom Cylinder Cover. I could then use the holes in the Bedplate to spot the 2.5mm holes in the Bottom Cylinder Covers and tap the holes M3. The threads on the rod closest to the small end were adjusted so the cylinders moved freely. The photo above shows the cylinders and covers mounted on the Bedplate.



Steam Chests

I managed to source some 6 x 12mm and 5 x 12mm brass flats and decided to use these to fabricate the Steam Chests. I used a Junior hacksaw to cut the pieces of brass and milled the two end pieces so they were the same width – right photo.



The end piece with the gland part was heavy so I decided to pin it to the long side-piece – left photo.



Even then the parts moved a bit while silver soldering/brazing the parts so may be small brass screws next time, the photo to the right shows one of the brazed Steam Chests after pickling and a few strokes with a flat file on the underside.



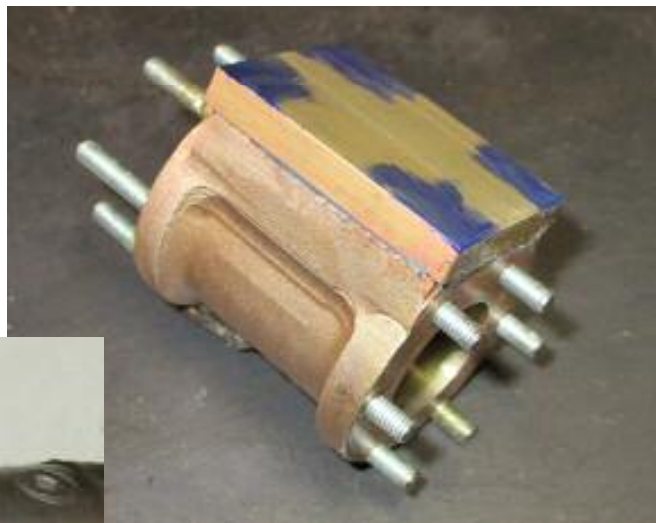
The work was then transferred to the milling machine and top and bottom milled flat – right photo. I will probably mill away a bit on the inside after drilling the holes for mounting the Steam Chest to the Cylinder.



The work was then transferred to the lathe and mounted (with packing) in the 4-jaw, so the hole in the gland could be drilled and tapped – left photo. To drill the smaller hole in the other end I used a long series Centre Drill to make a mark and then a long 2.5mm drill.

Port Block

After I had made the Steam Chests I realised that the Valve Rod would hit the Bearing Block unless I bent the rod. In the end I decided to soft solder 5mm thick brass Port Blocks to the Port Faces of the Cylinders – right photo. I tinned the mating surfaces first.



After soft soldering the brass flats to the Port Faces of the Cylinders I marked out positions in each corner and drilled a 2.5mm hole through the brass flat and around 4mm into the Cylinder. The holes were then tapped for M3 studs (well, pieces of threaded rod) – left photo.

After drilling and tapping the four holes in each portblock the next job was to mark out and mill the Steam Ports.

First I drilled a 1.5mm hole near the ends of the 1.6mm steam in ports to a depth of just over 4mm, so the tiny slot drill would have an easier job. I managed the four slots without breaking the tiny slot drill.

For the exhaust port I used a 3mm drill first before milling

I could then just turn the work 90 deg. in the dividing head to drill the passage from the exhaust port to the outside – right photo.



The photo to the left shows the steam chests mounted, I still need to drill some holes for letting steam into the steam chests.

The Steam Chest Covers were made from a piece of 1.5mm thick brass sheet. I could use the four 3mm holes in the Steam Chests as a drill jig so it was easy to get the covers to fit – right photo.



Slide Valves

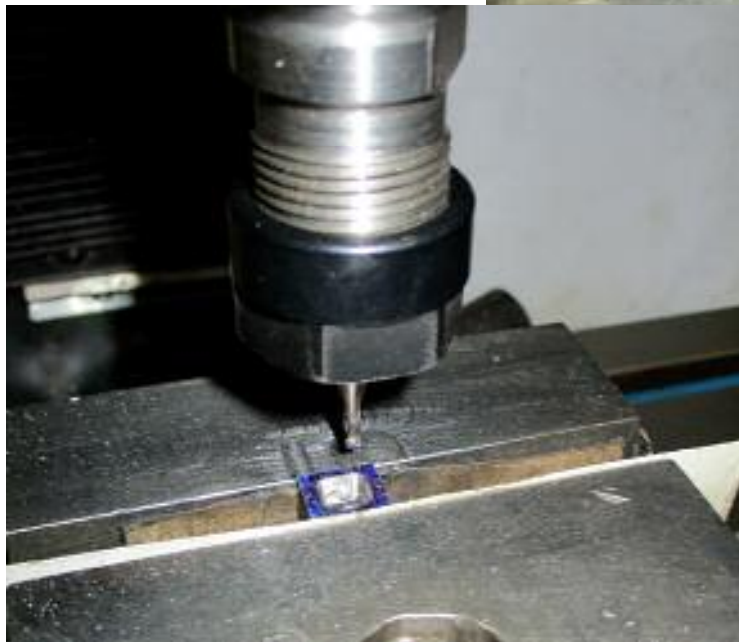
The Slide Valves were made from a piece of free-cutting (303) stainless steel rod.

I clamped the rod in a small 4-jaw independent chuck in my lathe and used a DTI to centre the work, and then faced the end. A 5mm slot drill was then used to mill a small cavity in the faced end. The cavity was nearly 2mm deep.



The 4-jaw with the work could then be moved to my indexer on the milling machine table, and the end milled to get a rectangular form 9mm wide and just over 10mm high. Two 3mm holes were drilled at 90 deg. and 4.5mm in from the end – right photo. This will give a rounded bottom in the slots that will be milled later.

The 4-jaw with the work was then moved back to the lathe and the valve parted off.



The parted off valve was mounted in the milling vice and a 2mm slot drill used to mill the cavity to dimensions using the handwheel dials – left photo.

The last operation was to mill the two 3mm slots, one slot for the Valve Rod, the other for the Valve Nut – right photo.



The left photo shows one of the finished valves.

Valve Rods & links

The Valve Rods and links were made the same way as the single cylinder slide valve engine I had made earlier. The rod was clamped in the ER-32 chuck on my small lathe with just a short end protruding, this was turned down to just under 2.5mm. Then the rod was moved out a few mm and that part turned down to 2.5mm, this was repeated until a length of about 9mm was turned down to 2.5mm. Then a M3 die in the tailstock dieholder was used to cut the M3 threads for a length of about 12mm. The work parted off at correct length and the other end threaded M3, the final Valve Rod is shown (with temporary nut) to the right.



The Valve Rod is connected to the Eccentric Rod with a small link. The link is made up of a fork like part with a pin and a rod that fits in between the fork.

The fork like part was made from a piece of 12mm steel bar. The bar was first mounted in the lathe chuck and turned down to 5.5mm for a length of 5mm. A 2.5mm hole was drilled to a depth of 5mm and tapped M3. The work was then transferred to the indexer on my milling machine and milled square – right photo. One side is 5.5mm AF, the other almost 6mm.



Two holes were drilled at 90 deg and a bit offset. One 2.5mm hole and one 3mm – right photo.

The 3mm hole is closest to the M3 threaded hole and will give a nice rounded bottom for the milled slot.



The work was then transferred back to the lathe and the fork parted off and then a file used on the corners. The left photo shows the finished fork on the Valve Rod.

The Eccentric Rods were made from a length of 3mm dia. mild steel rod.

I used the ER-32 chuck on my small lathe to hold the rod and face and chamfer the end before using a M3 die in the tailstock dieholder to cut the thread.

The rod was moved further out in the chuck and parted off to the correct length.

The parted off rod was then mounted in the ER chuck and chamfered and the M3 thread cut. Two rods were made.

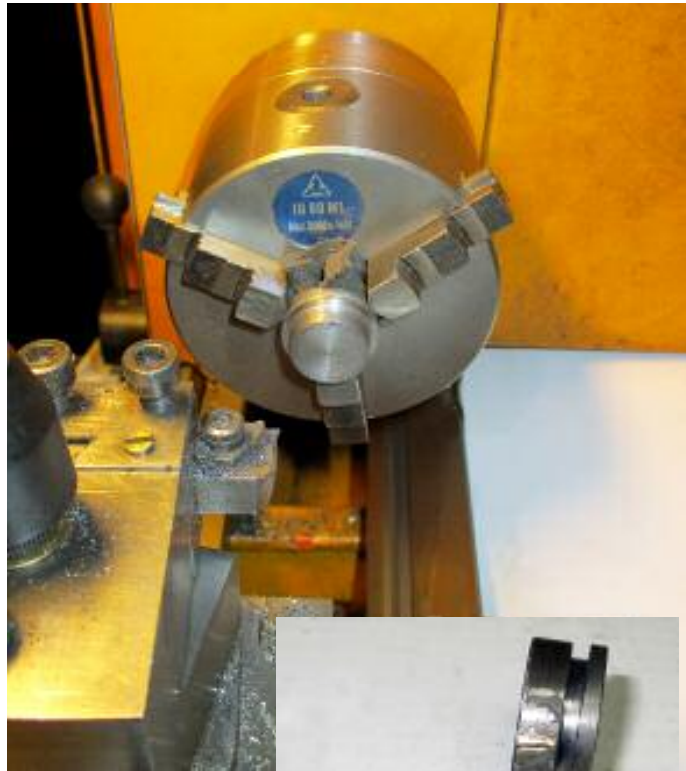
A piece of 6mm dia. mild steel rod was used to make the Eccentric Rod heads. The rod was mounted in the ER chuck and the end faced and chamfered. A 2.5mm hole was drilled to a depth of between 4 and 5mm and threaded M3 with a tap. The work was then transferred to the indexer on my milling machine and the non-threaded part milled to just under 3mm across flats. A suitable hole was drilled through the flats so a pin could be inserted – see above photo.

The above photo also shows that one of the Steam Chests is connected to the compressor using a small adapter I made for another single cylinder steam engine. Since I used the same distance between the mounting screws on the steam chests of both the single cylinder and the two-cylinder, I could use it to test one cylinder at a time. After giving the flywheel a spin the two-cylinder started running even if only one cylinder received any air.



Eccentrics

I made the eccentric sheaves from pieces of cast iron I had left over from another project. Instead of turning a groove in the sheave and using a split eccentric strap I simply turned a shoulder. To prevent the strap from falling off a thin piece of mild steel plate is attached with a couple of small screws. Below is a photo of the sheaves after turning.



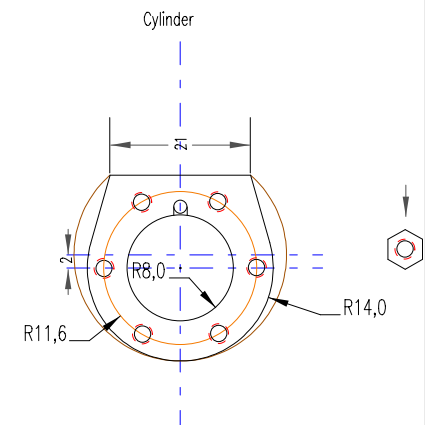
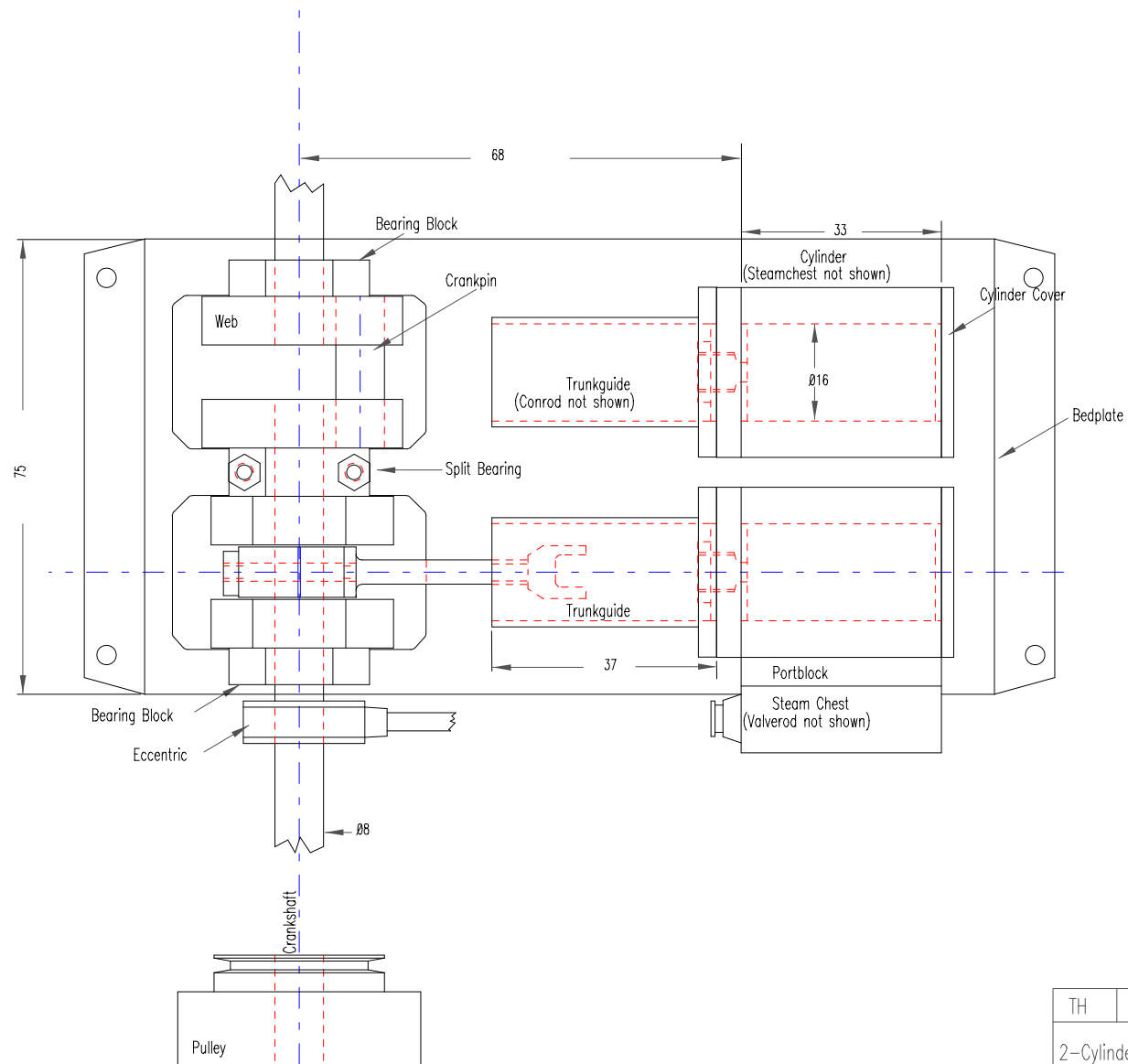
The straps were fabricated from two short pieces cut from a steel tube with 18mm I.D, and 22mm O.D. I silver (hard) soldered two small pieces of mild steel to the tube pieces. I will drill a 2.5mm hole in each and tap M3 for the Eccentric Rod – right photo.



Steam Connector

To be able to supply both Steam Chests with steam (or compressed air) I used a piece of copper tubing and some pieces of brass to fabricate a steam connector. The right photo shows the parts ready fluxed in my makeshift hearth.





TH	2017	Measurements in mm	⊙	□
2-Cylinder Steam Engine G.A. (seen from above)				
Material: Steel, Brass/Gunmetal				

