Shay Engine Machining

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These pages show some of the I techniques used to machine the Shay engine parts. The first engine parts machined were the cylinders, crosshead guides and valve stem guides. These were done before I though to take photos. The critical facing and boring of the cylinders and crosshead guides was done on the lathe using a 4 jaw chuck. The heads were also turned on the lathe. A drilling template was very carefully fabricated and used to drill the attachment holes in the heads, cylinders and crosshead guides. This permitted these pieces to fit together in correct alignment.

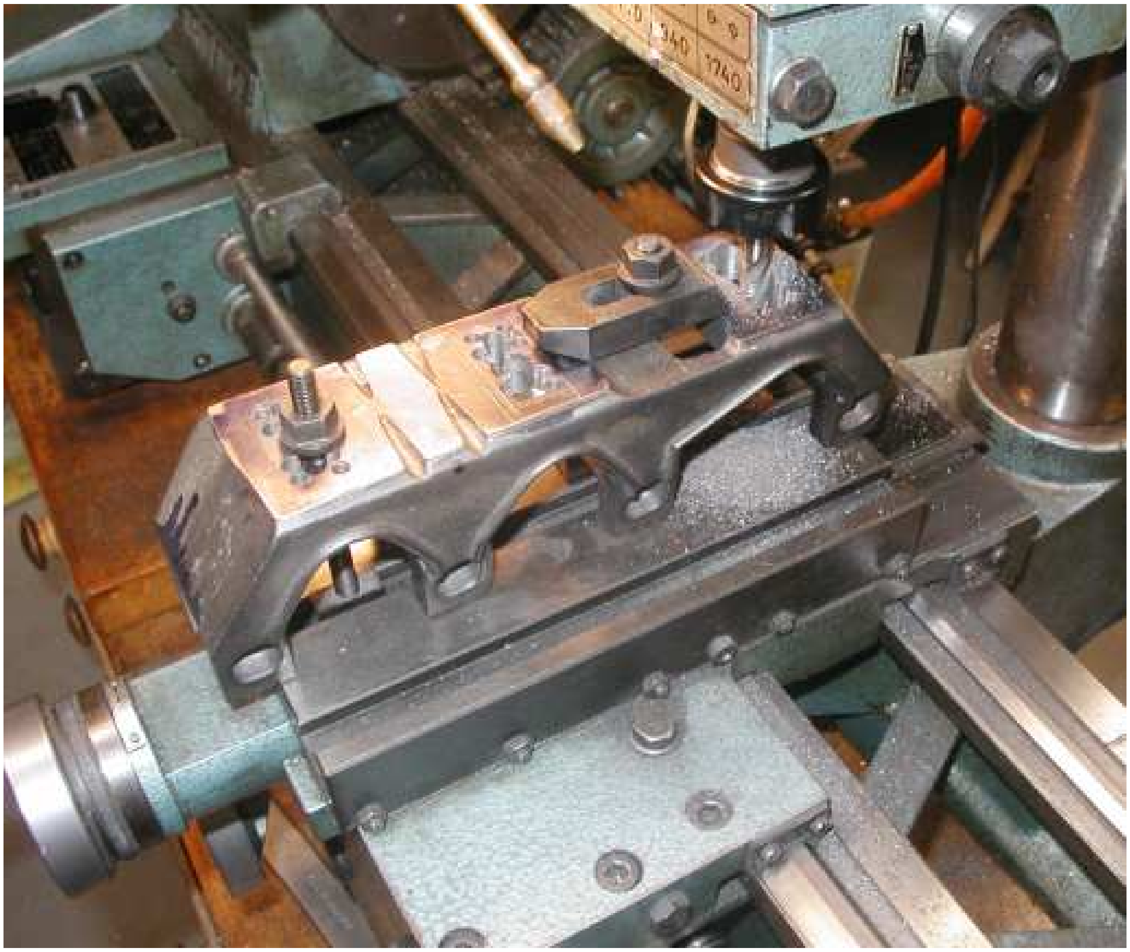
The next step was the machining of the crankcase casting. First, the upper surface was milled flat to form the reference surface. The rear mounting pads were than milled flat to form a second reference surface. The slots for the main bearings were next. Much of the material was removed using the drill press before the finial milling operations. All four slots were machined at the same time as shown on the right. This insured perfect alignment.

This photo shows finishing the bottom surface of the crankcase to accept the bearing retaining caps. This was done without changing the casting from the bearing slot machining above to insure perfect alignment of the caps.

The cast iron is an excellent material to work with. It machines easily because it tends not to grab the tools; the removed material comes off as small chips, or fine sand like granules or a powder. There is however one drawback; the debris sticks to hands and clothes leaving a dirty black residue. After washing, the residue is transferred to the bottom of a sink or shower where it turns to rust in a few seconds, much to the displeasure of the domestic staff.

The final major operation on the crankshaft was to mill out the holes for the connecting rods and #2 cylinder valve eccentric blades. Rough holes were made on the drill press and finished on the mill as shown on the right.

After the major machining over 50 holes had to be drilled and tapped. Drilling templates were made for the bearing caps and crosshead guides to insure all the holes on mating pieces lined up correctly.

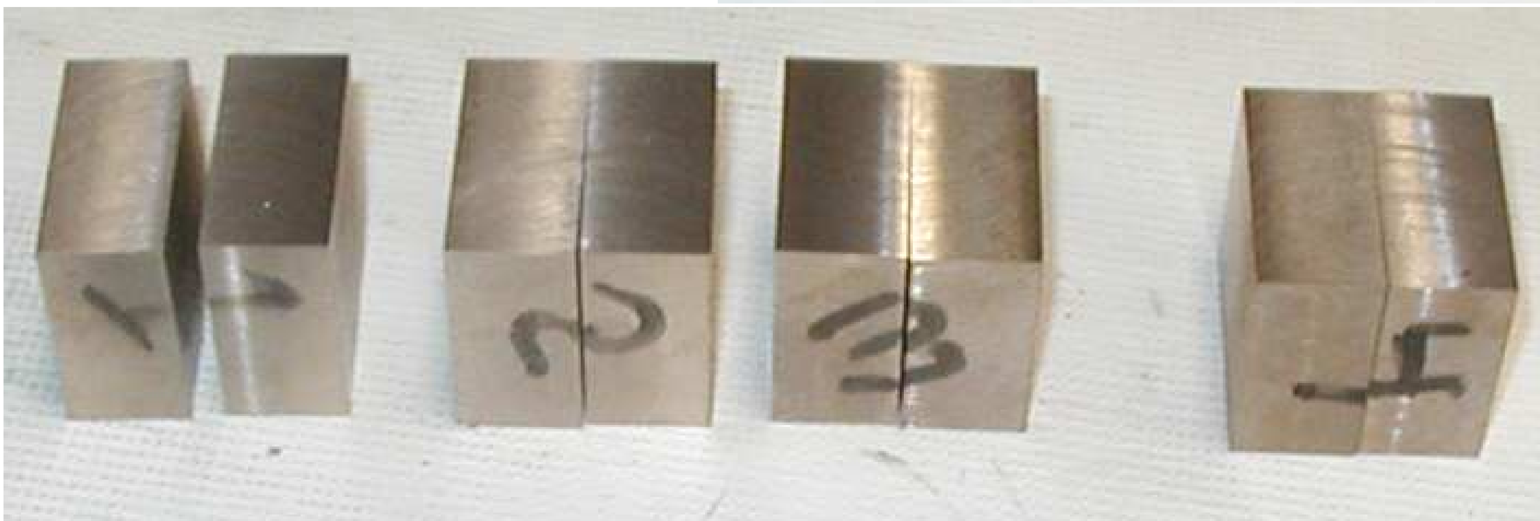


The main bearing retaining caps were fabricated from cold roll steel stock. The photo at the right shows milling a recess in the caps. Note that all four caps are aligned in the milling vise and the slot in the four caps is done in one operation. This insured that all caps were in alignment.

The main bearings were fabricated from 1.75" bronze bearing stock like that shown on the right. This stuff is really expensive, going for over three dollars per linear inch.

The first step was to cut off a piece the correct length for each bearing. Then each one of these pieces was cut in half as shown on the right.

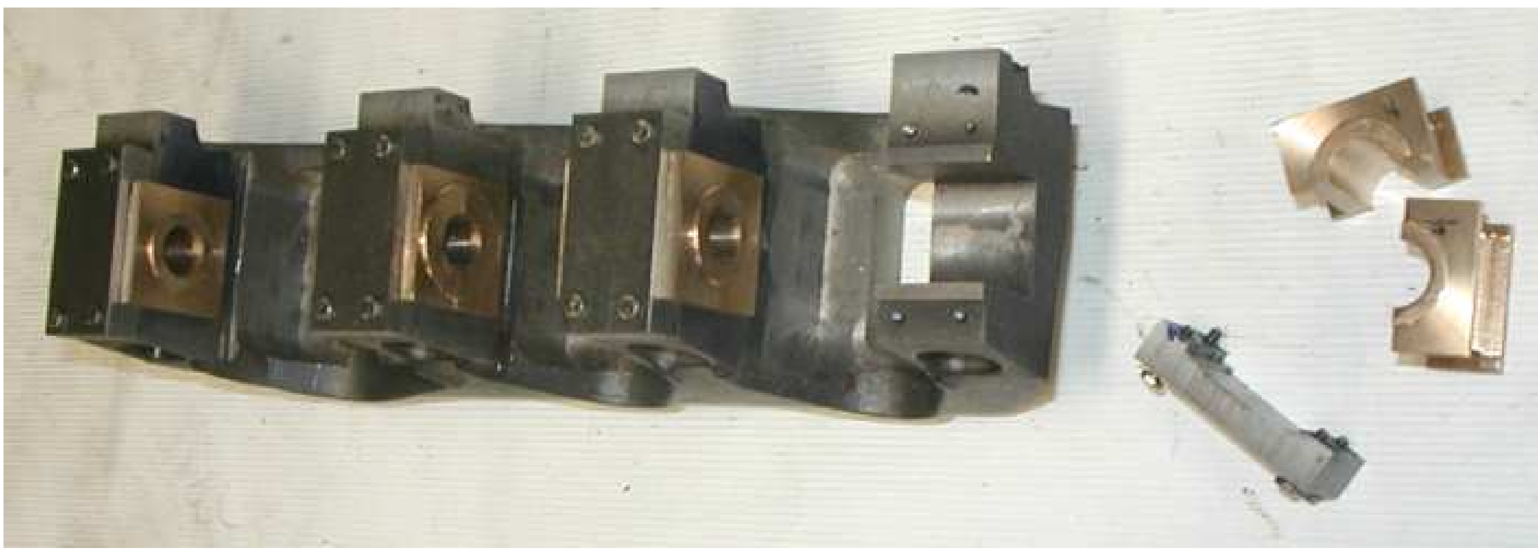
Next, the pieces were machined flat and to the correct dimensions in the mill.   The final milling operations were done on all pieces using the same settings to insure uniformity. These blocks are shown in photo below.



Next, the center holes were bored (slightly undersize) and the ends faced in the lathe.

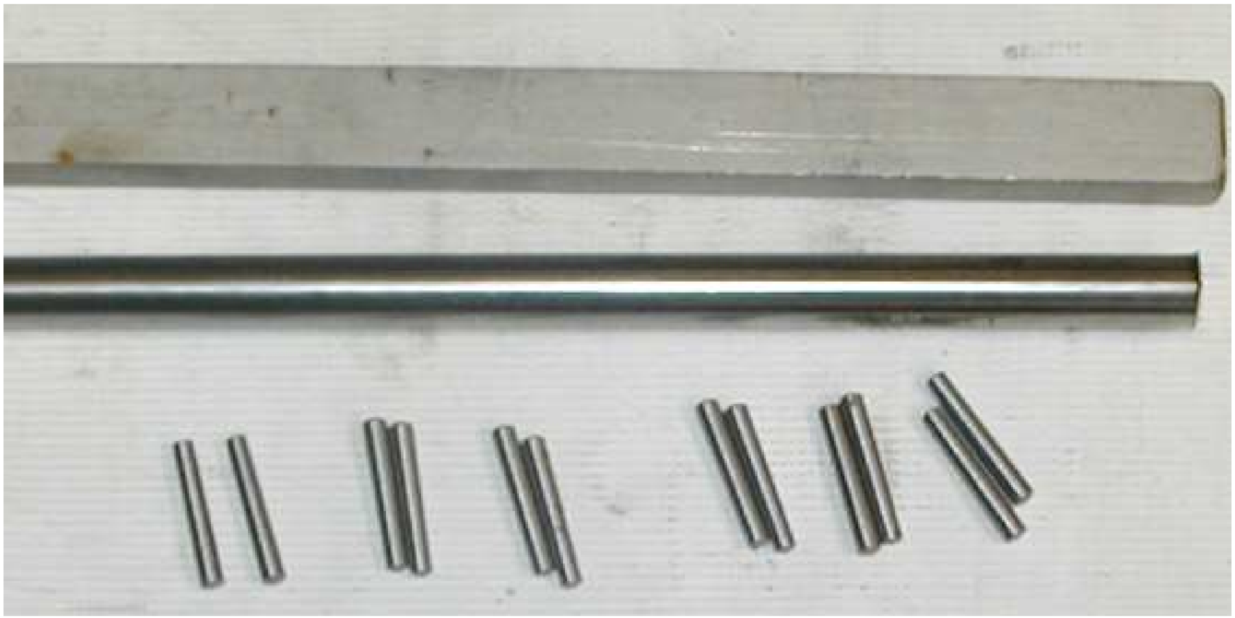
Recesses were then milled in the sides of each bearing. The recesses matched up with the slots in the crankcase as shown in the photo below.

The final operation was to ream the holes to the exact inside diameter using a toolmaker's reamer fabricated from drill rod. This long reamer passing through all the bearings insured correct alignment. .



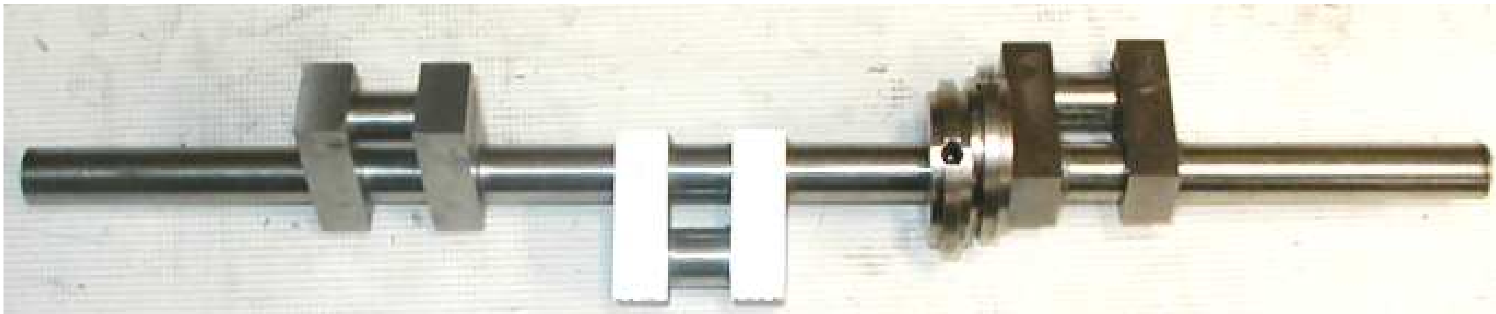
The crankshaft turned out to be less of a job than initially expected. Kenneth provided explicit instructions on how to make it. I ended up doing the job twice. The first time I used drill rod for the main piece. I somehow got the throw for one of the cylinders a little long. While there were some tolerances designed in, I though this error was pushing the limits (piston striking the heads) so I made a second crankshaft --- the second one took no time at all. I used precision ground stainless rod rather than drill rod on the second one. The photos below are mostly from the first attempt.

This photo shows the raw materials: stainless steel bar stock, rod and taper pins. (This photo is from the second attempt.)



The bar stock is cut and milled smooth and drilled to make the webs. The crank rods are then pinned in place on the webs using the taper pins.   The webs are then installed onto the main shaft and also pinned in place. The photo below show the middle crank in position.

The next photo show all three cranks in position, Note that the eccentrics for the middle cylinder are installed before the #1 cylinder crank is positioned on the rod.

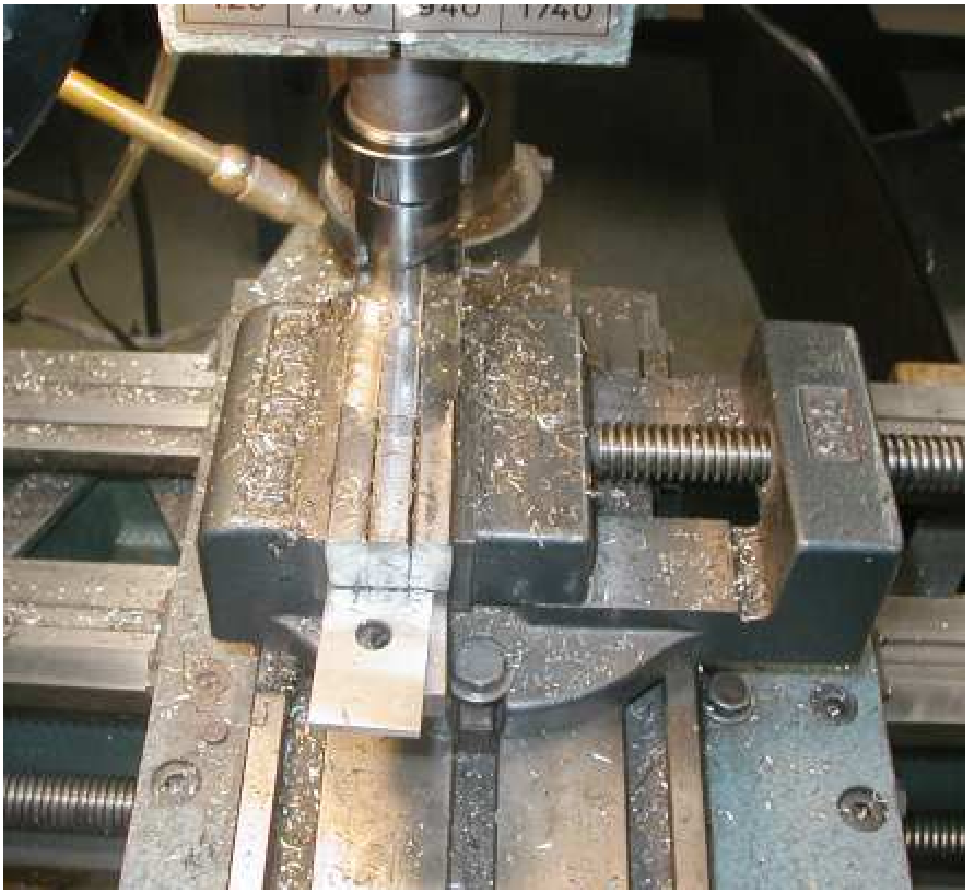


The next photo shows the completed crankshaft after the rod had been sawed out between each pair of webs.

Here is the crankshaft in place in the crankcase.

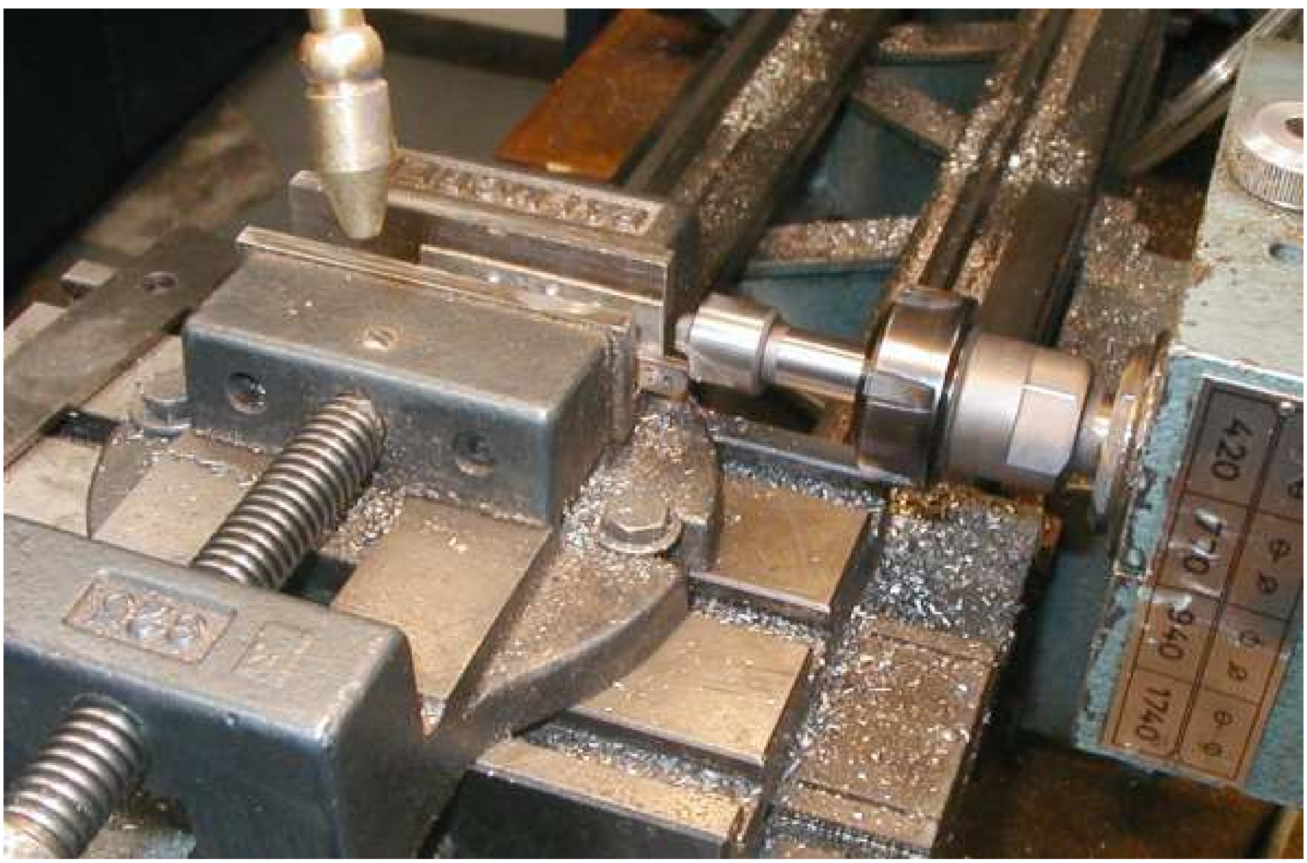
The connecting rods were machined from the three pieces of stainless bar stock shown below.

Most of the work on the rods was done by milling and all three rods were done at the same time wherever possible. The photo below shows finishing the sides of the three rods held together in the vise.



The photo below shows the nearly finished rods.

The next photo shows finishing the upper end of a rod to the proper radius with a corner rounding end mill.



There are a total of six bronze eccentric straps, two for each cylinder. The first step was to saw the part of the eccentric strap casting that goes around the eccentric in half and machine the mating surfaces flat. The outer sides of the straps were then machined using the mill. The photo at the right shows the six top halves held together in the vise and the top being milled smooth and to the correct height using a fly cutter.

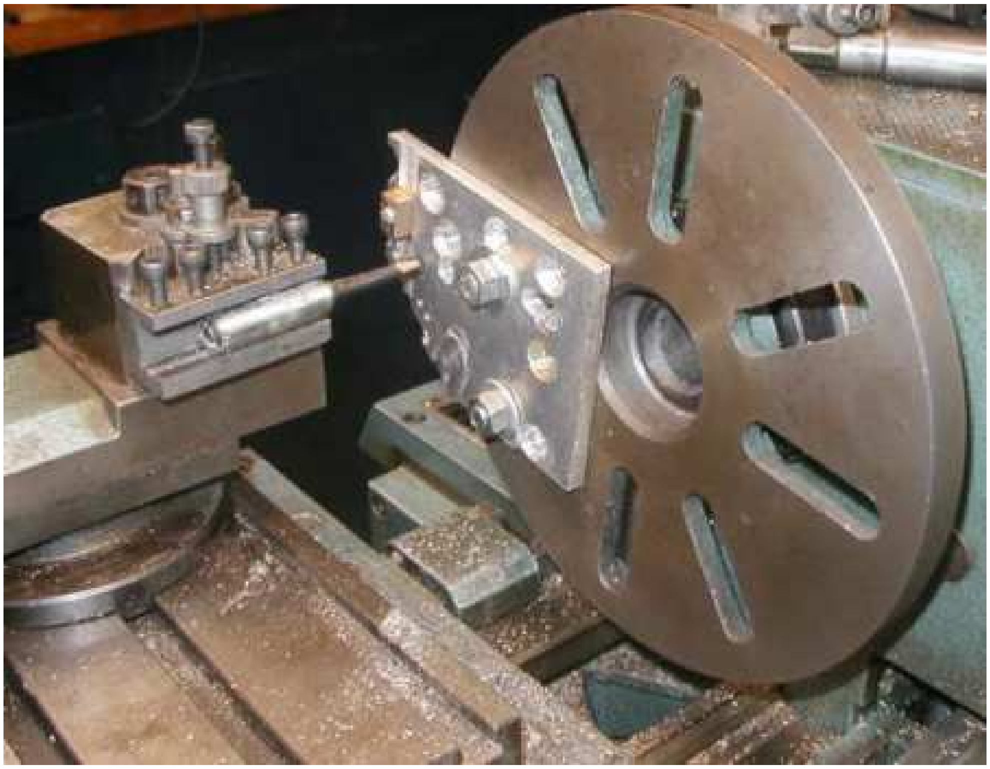
After this operation holes were dilled in both halves and the lower holes tapped so that the two halves of each strap could be held together with screws.

The photo on the right shows machining the side of one of the straps in the lathe. This same setup was used to bore the inside and to turn a groove to match with the eccentric.

The valve reversing link and link blocks shown on the right were some of the most difficult parts to fabricate. The slot in the link is at a 4 inch radius and there is a mating curve in the bronze link block that rides in the slot.

The photo on the right shows the setup used to mill that slot on the 4 inch radius. Before the slot was milled the three links were silver soldered together. This permitted three identical links to be machined. The outer surfaces were machined on all three at the same time and the holes also drilled through the three at the same time. The three links were then fastened to a scrap aluminum plate with screws. The aluminum plate was then secured to the lathe faceplate which was then attached to the rotary table. (Years ago I made a fixture for the rotary table identical to the end of the lathe headstock so that the lathe faceplate, chucks and collets can be secured and centered on the rotary table.) The links were then adjusted to the 4 inch radius from the center of the table and such that the radius bisected the links. The entire setup was then positioned under the vertical milling head and the table rotated to make the curved slot. (This is the only way I could think of to make that curved slot.)

The next job was to machine the sides of the link block to match the sides of the curved slot in the reversing link. The setup on the right was used for this operation. The first step was to machine the link blocks to the correct overall dimensions and with a hole in the center. A slot was then milled in the aluminum scrap, the link block positioned in the slot and a hole drilled through the scrap aligned with the hole in the block. The block was then secured to the scrap with a small crew. The scrap was then fastened to the faceplate such that the center of the block was 4 inches from the lathe center line and orthogonal to the radius. Both sides of the block were then turned to the correct shape. The second and third blocks took little effort using this setup. The blocks matched the slot in the link perfectly.



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