Shay Line Shafts & Universal Fabrication

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The following describes how I machined some of the parts of the line shaft. Recall that I'm not a machinist so it's very likely I found the hard way to make the parts.

Line Shaft Bearings: The line shaft bearings are made from round SAE 841 oil impregnated bearing stock. The first step was to mill the bar to a square shape. This operation is shown on the right. This turned into a real mess ---- puddles of oil ran out of the bronze. This got worse with each succeeding piece ---- the mill was rapidly dulling, it seemed more rapidly than I'd expect on steel. Some time later in a conversation with Dan Staron he commented that this type of bronze dulls tools quickly. Seems strange, the bronze is softer than steel and the oil should keep things cool. If I had it to do over, I'd do this on the lathe where the tool bit is easy to sharpen --- or use a fly cutter in the mill..

The next step was to mount the block in the 4 jaw chuck. The photo shows using the dial indicator to center the block in the chuck.

The next step was to turn the stub on the side of the bearing

The bearing was repositioned and centered in the chuck using the dial indicator and then centered drilled and drilled ~ 7/16"

The hole was enlarged by boring to slightly under 1/2" diameter. If the bar is centered, the boring makes a perfectly centered hole that is also round and straight.

The hole was then reamed to 0.501"

This shows the bearing and the journal box. The stub is a snug fit in the axel hole in the box.

The bearing installed in the journal box.

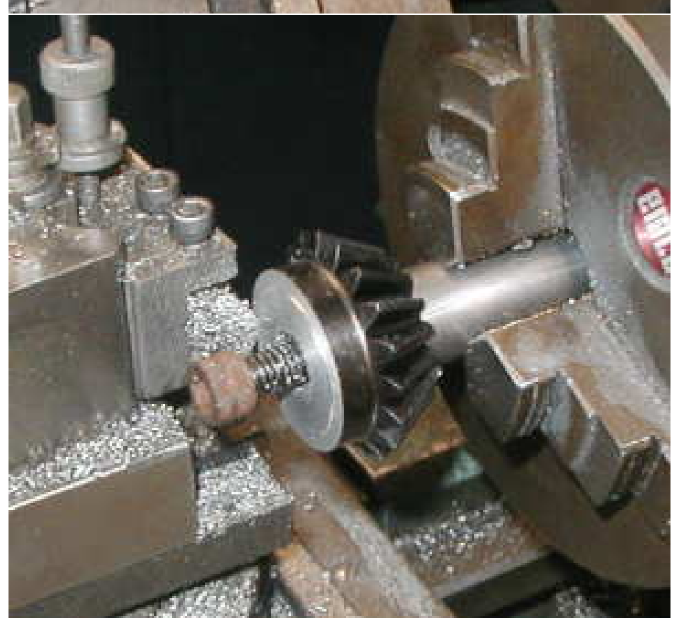
The line shafts runs through the two bearings on each truck. When I tried to shove the shaft through the bearings, I found the bearings weren't perfectly aligned --- no surprise. I then filed and milled the bearings as necessary to get the two in alignment. After everything was aligned I ran the tool maker's reamer I had used on the main bearings through the two bearings. This reamer is made from 1/2" drill rod but is flattened a little on the business end to make a 0.502"-0.503" hole.

Pinion Gears: The stock pinion gears must be shortened significantly.

The first thing I did was to saw off about 80% of the excess length.

Next, I made a 1/2" ID mandrel as follows: The end of a 3/4" diameter rod was turned to a little over 1/2". Next, the end was drilled and tapped part way 5/16"- 18.   Two saw cuts were made down the length of the ~1/2" diameter end. The rod was the remounted in the check and turned to exactly 1/2".   The result is an expanding mandrel --- as the screw in the end is tightened into the partially threaded part the rod the end expands......

This photo shows finished the end of a pinion gear. All gears were finished before the mandrel was removed from the chuck.



Universal Joint: This is the stub part that mounts on the line shafts and crankshaft. I started by cutting a piece of 7/8" rod and chucking it in the lathe and drilling a 1/2" hole through the center. The rod is extra long at this point. Next, one end was cross drilled 3/8" in the drill press. I found the cross drilling worked the best by first center punching the spot, then use a center drill to improve the center punch mark, then drill 1/4" and finish by drilling 3/8". During these steps I repositioned the rod in the drill press vise as necessary so that the hole went through the center of the bar. The 3/8" drill has a tendency to grab the piece, so excitement is minimized if a large vise is used and it is grasped and held firmly.

The rod was then cross drilled and tapped for two 1/4-28 set screws. (These were made after I decided to not pin the parts to the line shaft.) The end was sawed off to near midway through the 3/8" hole. The rod was then put in the lathe to true up the two ends and ream the center hole to 0.501". The photo shows the completed rod and pin. The pin is 3/8" diameter, 1.760" long and 0.260" of each is turned to 0.250" to match the little sleeve bearings in the universal ring.

The next step was to silver solder the pin to the end of the rod. The parts were cleaned in a pickling solution, fluxed and then small pieces of silver solder were placed next to the joints as shown on the right.

After the silver soldering the center of the pin was cut out with a hack saw.

Next, a 1/2" diameter end mill was used to finish the recess in the end of the rod.

This shows the finished U joint stub. After doing several of these I examined the solder joints and became concerned. The silver solder joint is very strong if the silver solder has flowed into the joint between the two pieces. However, there appeared to be areas where the solder hadn't flowed. *I could envision running the engine flat out, the rear universal on the middle truck coming apart, the front end of the rear drive shaft dropping down between the ties making the tender into a catapult hurling me 15 feet down the track where I'd be then run over by the locomotive. ---- sounds like a great home video.* I unsoldered one of the joints and indeed it wasn't a good joint.

My guess is that the soldering difficulty had to do with the joint geometry. I cleaned up the rods again and this time placed some strips of flat silver solder in the recess and then set the pin (a new one) on top the recess. The pin was of course setting well above the base of the recess. When heated the solder softened and the pin dropped down into the recess. I tapped the top of the pin with a small hammer to make sure the pin was in the proper position before removing the heat.

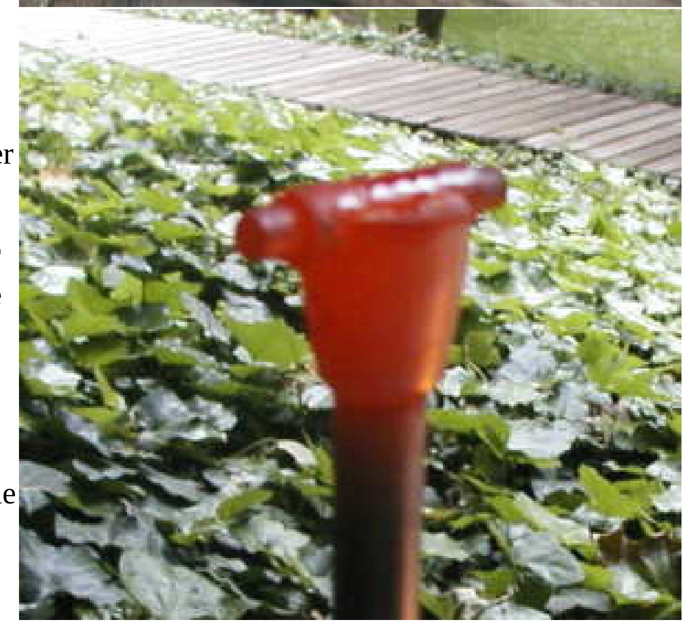
This shows a joint right after it was soldered properly. It's still very hot, hence the pliers. Note the bead of brass colored solder all around the soldered spot. This bead looks much like a sweated copper plumbing pipe joint. The bead should be visible and uniform on both sides of each soldered joint. That's hardened flux that has flowed below the pin.

The pin was sawed and the end finished with a mill again as described above. The top of the pin was ground flat and inside corner rounded as shown on the right. The part was then soaked in the pickling bath again to remove flux reside. The acid was then rinsed of with cold water, the part blown dry and then coated with WD40 to keep it from rusting.

Silver Soldering: Before starting the Shay I went to the local welding shop to inquire about a propane burner for silver soldering. The old guy in the shop said you can't use propane, it doesn't get hot enough. The live steam books say to use propane. Ignoring the welding guy's advice, I bought the setup shown here. The tank is from an old gas grill --- the type that the suppliers will not fill to use to prepare food. You can however get it filled to use with a torch. (If I have a half cooked steak when the barbecue runs out of propane, I will of course not connect this bottle to the barbecue --- it's against the law!) I use the burner outside because of fumes and the huge flame --- it's like a small flame thrower. I set the parts to be soldered on the bricks. The wife has become concerned that the ivy seems to be dying near the bricks. I told her it was probably the dreaded "English Ivy Fungus". If looks could kill........

This shows the burner in more detail. (It also shows a burned ivy leaf --- damn fungus!) It's the Swedish Sievert brand which I purchased from [Sulphur Springs Steam Models]

Each part is sold separately:
SIEVERT REGULATOR: #3060
SIEVERT PROPANE GAS HOSE #3512
SIEVERT #3488 UNIVERSAL HANDLE
SIEVERT #3501 neck tube
SIEVERT NECK TUBE SUPPORT #7172
SIEVERT BURNER # 3940 (the small one)
SIEVERT BURNER # 2943 (the one on the handle)
SIEVERT BURNER # 2960 (the big one)



I also bought brazing supplies from Sulphur Springs including white silver brazing flux, pickling solutions for steel and for brass and the silver solder. I prefer the 45% silver solder in 1/32" diameter and the flat strips. The pickling solutions come as dry salts like soup concentrate --- you just add water. The solutions must be heated to about 140 degrees F to work properly. A crock pot works great for heating the solution. I've also purchased some 50% silver solder flat strips from McMaster-Carr that work great.

The parts need to be heated deep red for the solder to flow properly. The flux flows just before the part turns red. Steel is not a great heat conductor so it takes a couple minutes to heat a part like the end of a male drive shaft slip joint shown on the right. I used the #2943 burner (the medium sized one on the handle in the previous photo) for this job

Caution: These burners throw a long flame ---- several feet so be careful where you use it. Also, the solder contains cadmium which gives off a poisonous vapor when heated. Silver soldering is best done in a large well ventilated area --- or outside as shown here.

Check out the accompanying note on fabricating the universal rings and drive shafts.

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