Machining a 4-Step Pulley

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Scope

With a rough castings in hand, it is time to turn it into a pulley. This article deals with this process using a lathe and mill. Next to the casting is the pattern I used. It is made of stacked disks of 3/4" MDF. No paint or lacquer was used.

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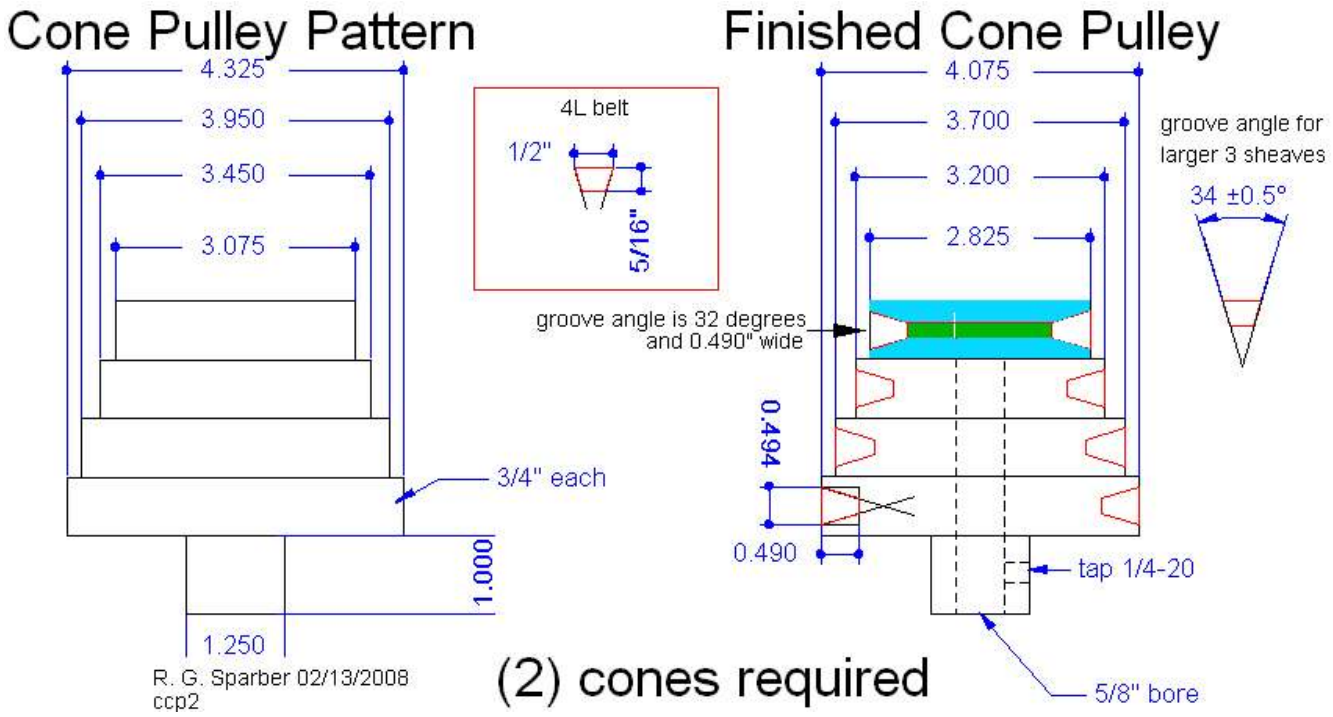
The finished product – ta da!

What am I making?

I mostly followed the pattern plan but decided that the stub was not necessary.



You may notice that I have not specified the over all length of the pulley. The plan was to remove as little metal from the two faces of the pulley as possible and then evenly distribute the four grooves. Later I will make a matching pulley and will use the same spacing. In this way the grooves will match up between the two pulleys.

Where Am I?

An essential first step in machining a casting, especially the sad looking ones that I make, is to figure out its initial shape. This means taking measurements so it becomes clear how best to cut your reference surfaces. In the case of a pulley, the reference is the centerline.

I can see a lump on the narrow end of the casting but around it is fairly flat.

I don't want that lump in my way so have put the casting on small parallels which rest on my surface plate. I then used my surface gage to see how true the wide end is with respect to the narrow end. The more I must remove from the ends, the less thickness I'll have for the individual steps of the pulley.

Much to my surprise and delight, the wide face was high at one side by only 0.014” and low on the opposite side by 0.016”. This can easily be removed without seriously effecting the width of each step.

OK, time to clean up the casting a bit.

Initial Clean Up of the Casting

The wide end of the casting has the sprue attached. It does not look like a normal sprue because I almost ran out of aluminum during the pour. The lack of a longer sprue means that the molten metal's pressure is less so the surface is not as smooth. No matter, I am going to cut all of the surface away. Note how the sprue is concave. This is due to shrinkage as the metal changed from liquid to solid. Fortunately, only the sprue shrunk and not any of the casting.

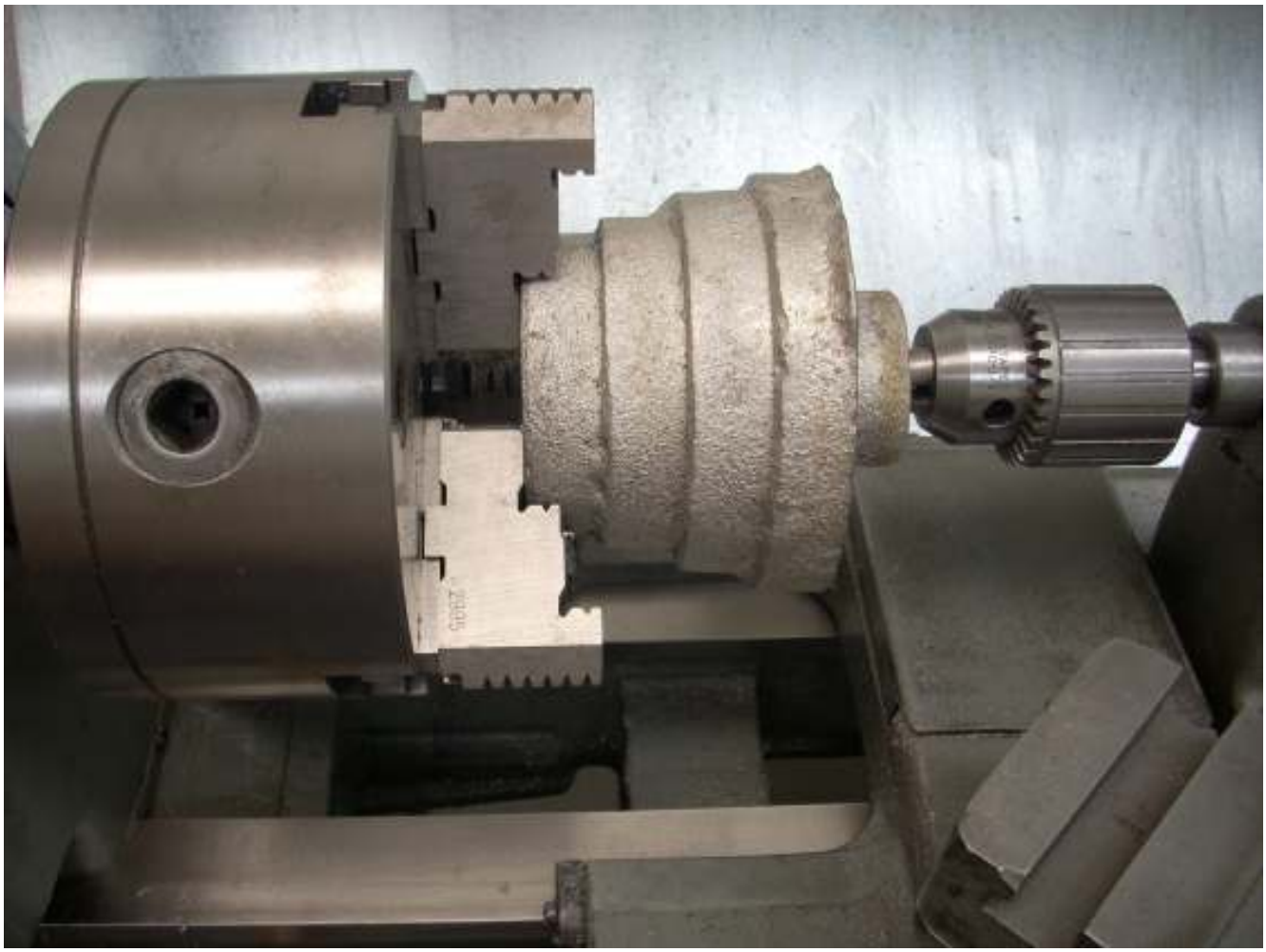
Another reason (excuse?) for the less than ideal surface finish is that my Petrobond casting sand was very dry and its green strength was poor. I have since rejuvenated it so will need a new excuse next time.

The sprue has served me well but it is now time to remove it. No waste here, it goes back into my pile of metal to be turned back into new castings.

The casting has been securely clamped into my horizontal/vertical bandsaw. Note the packing in mostly blue under the sprue. Without this packing the casting would soon pivot, pinch the blade, and the blade would either pop off of the drive wheel or snap. A bit more time now avoids that excitement.

The saw is now starting to cut through the sprue. Note the white block of paraffin wax to the left of the sprue. It is just resting there and is being cut by the blade at the same time. This is a clean and easy way to lubricate the blade. The bits of cut metal coated with wax fall out the other side. The blade does not pick up any wax.

Nice and uneventful cutting off of the sprue.



Being careful to avoid the lump on the small end's surface, I am bedding the casting into my 3 jaw chuck. My drill chuck is applying light pressure as I tighten the jaws. Careful inspection of the contact between jaws and casting insures the part is properly bedded.

No, I'm not taking a cut, just using my cutter to verify the casting is bedded. By slowly turning the chuck by hand, I can see the gap between cutter and wide face vary. It looks good.

Machining this part so precariously held in the chuck would not be smart. However, it is fine for drilling a hole so a mandrel can be fitted. The finish hole in the pulley will be 5/8” so that will be the diameter of my mandrel too. This is a lot of metal to remove so I will do it starting at 1/4” and going in 1/8” steps to 5/8”.

Before using each drill, I sharpen it on my trusty Drill Doctor®. I don't own stock in this company nor sell them. However I do benefit from their product every time I drill a hole. All but my 5/8” drill fit.

Step drilling minimizes the force on the chuck to avoid any “excitement”. Given enough twisting force from a large drill being used to hog out the hole, the casting can fly off.

The most time consuming hole was the first one. I used plenty of cutting fluid and went in 1 to 2” at a time. After going in a short distance, the drill was removed and cleaned of chips. More fluid was sprayed into the hole and the cycle repeated. The larger the hole, the more room for chips but I still went in only 1 to 2” at a time.

With the 5/8” hole done, it was time to make the mandrel. Nothing fancy, just a piece of 5/8” steel with both ends center drilled to take the dead and live centers of the lathe.

The mandrel was fitted to the casting and moved to my mill/drill where the set screw hole will be drilled and tapped.

In my continuing effort to avoid “excitement”, time was spent being sure the casting was securely anchored to the mill's table. The casting was supported by the mandrel. The mandrel was supported in V blocks set on 1-2-3 blocks. Hold down clamps pressed down on the top of the mandrel. To prevent rotation of the casting, a large C-clamp pushed against the ends of the V blocks. .

I did my best to eyeball the centerline. It would have been more precise if I had set my V-blocks true but this was good enough. Many times saying something is “good enough” is really just another way of saying I'm too lazy to do it right. On the other hand, I don't want to waste time on this non-critical hole when there is a lot of work ahead of me. As always, a balance must be struck.

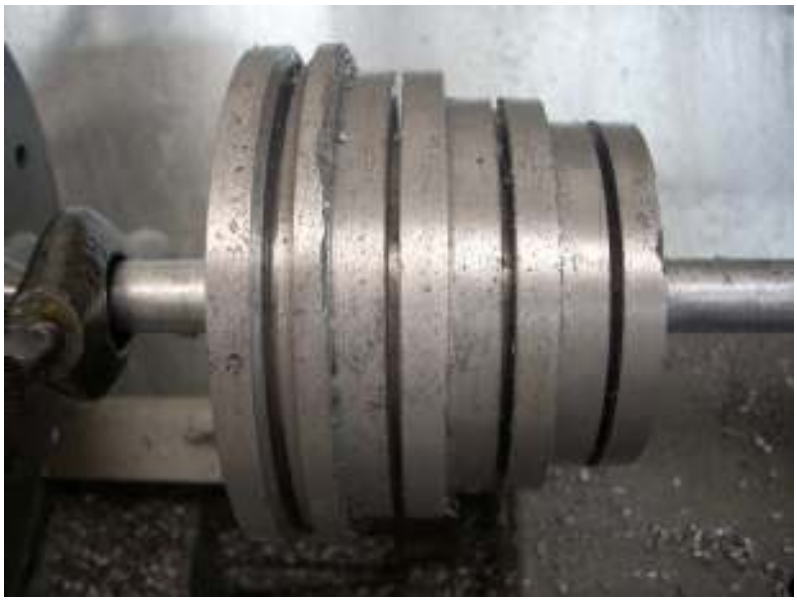
My tap can thread about 1” of hole but this hole is around 2” deep. Not to worry. I just drilled a clearance hole for the tap body down about 1.5” and then the tap hole the last 0.5”. The set screw is about 1/4” long so this is plenty of thread.

Somehow I misjudged the thickness of the aluminum by about 1/4” and drilled into the mandrel. This turned out to be helpful since the setscrew locked into this hole to better prevent rotation of the casting on the mandrel without leaving a burr.

With the mandrel fixed to the casting and a dog added, the assembly was mounted onto my lathe.

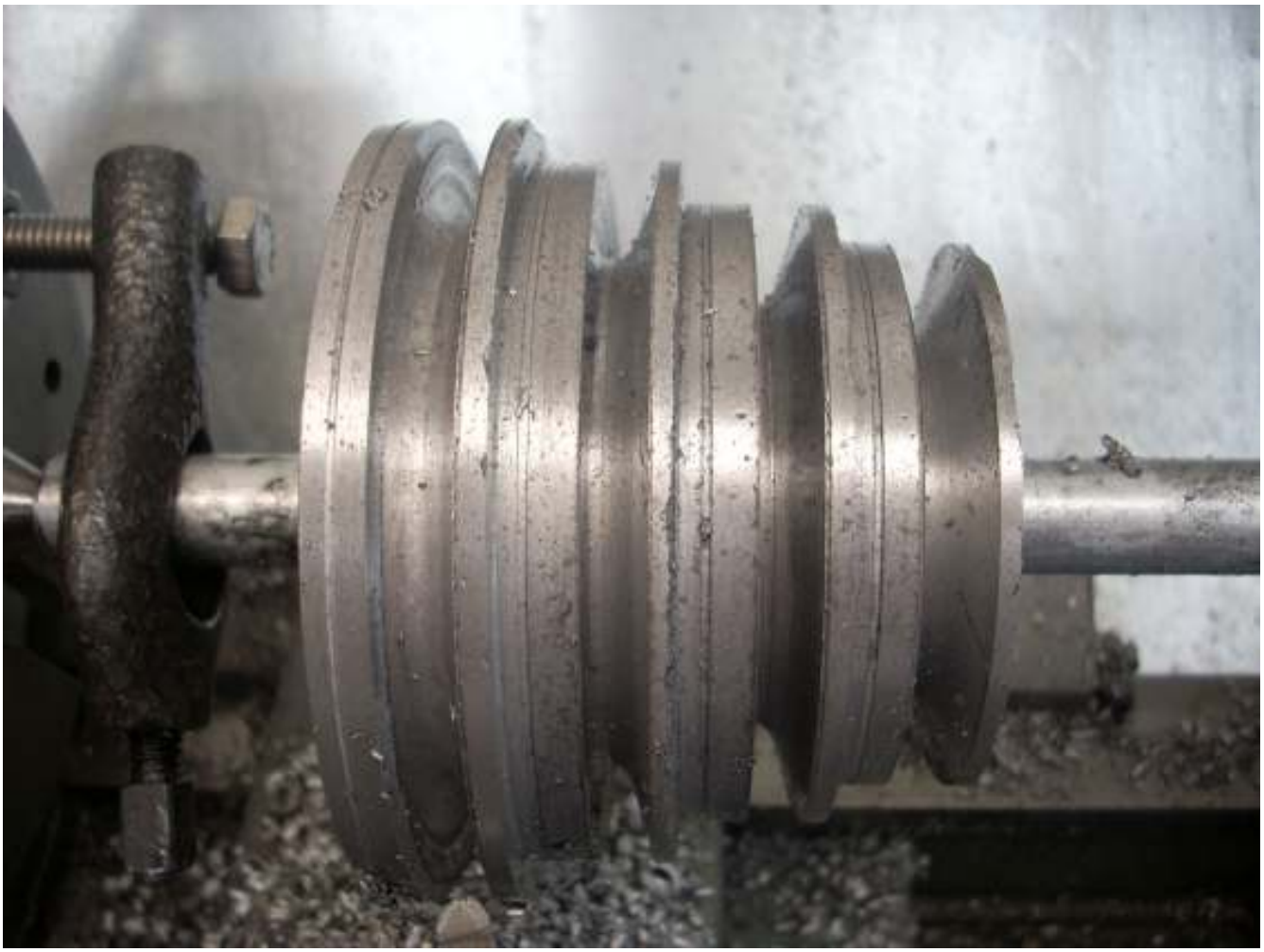
Initially I used a generic cutting fluid from Enco which worked OK but WD-40 gave better results so the remaining work was with it.

The wide end of the casting was cleaned up first and while I was at it, I turned the largest diameter. The assembly was then turned end for end to reach the remaining steps and the narrow end.



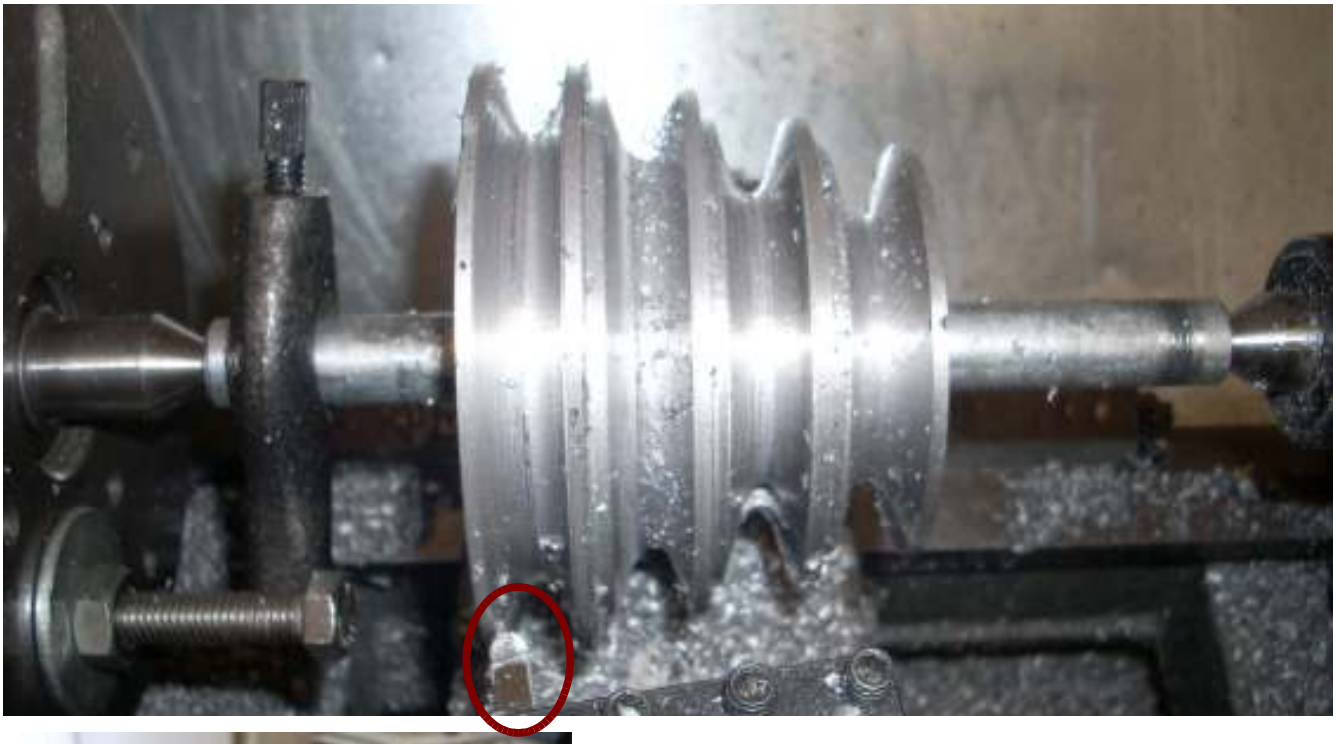
I've skipped a few steps. You see here that all four steps have been finished to their final diameter and the narrow end faced off. I measured the over all length of the part and calculated the center line of each groove. My cut off tool was then used at each centerline to cut down to the bottom of each groove. A second pulley will be made later and it will match this spacing of grooves.

The depth is not a precision dimension. I just want to know when I'm in the neighborhood. Note that the largest diameter groove is a bit wider. I initially tried to mark the depth with a regular round nose cutter but it was too much of a load.



The compound was set to 17 degrees. I initially mounted a round nose cutter at this same angle. This worked OK but I later realized that the cutter is best set perpendicular to the mandrel or even pointing towards the surface being cut if there is no interference with the opposite face of the groove. Here you see the right face of each groove done. I eyeballed its placement. The left face will be set, as per the plans, to the width of 0.494”.

The left face of all grooves is now done. Note, inside the red circle, that I have pointed the cutter slightly to the left. The surface was a little rough so I used 120 grit emery cloth to improve the finish.



In hindsight, it would have been easier to first plunge cut the full width of the bottom of each groove. This would provide the maximum space for the cutter to form the sides of the groove. A second realization was that my cutter for the sides of the groove had a small chip in it. This caused the finished surface to be rough. The cutter was resharpened on my belt sander and then finished with a stone. It now cuts a nice smooth finish when WD-40 is applied as a cutting fluid.

My machined surfaces came out fairly well. The roughness you see is where the original rough cast surface was not machined. It is not pretty but is certainly functional.

I have a second pulley to make identical to this one. Since I learned a few things, hopefully I can do a better job and take less than the 8 hours it took to make this one. Oh yes, I did trial fit a belt in the grooves and it fits nicely.

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PS: The second pulley took about 4 hours to make and I did not need emery cloth to smooth the grooves. I did manage to screw up the final cut and lopped off 0.1” of shoulder on the smallest diameter. Oh well, nothing is perfect. It will still work.