"Fitting steel tyres to a locomotive"

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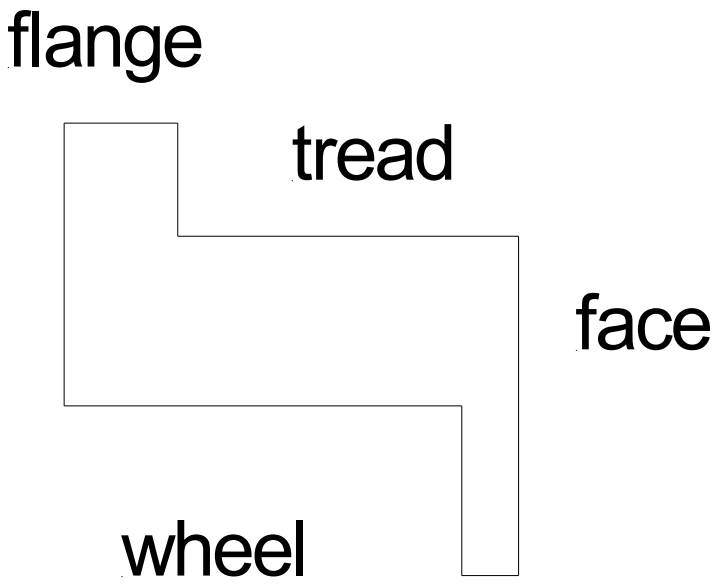
A few days ago I was asked for some advice on how to fit steel tyres to a locomotive. This had come about because the locomotive in question was clocking up a fair few miles and being a small wheeled design, the wear was quite rapid, to the point where the wheels were becoming double flanged. This was not a surprise to me as Hernia used to suffer this problem, to the extent that the wheels had to be reprofiled every couple of years until we fitted steel tyres. That was almost 20 years ago, since when no attention has been needed and there is little sign of wear. So whilst I was making the wheel sets for Fred, I fitted tyres, from new. I am doing the same with my own projects, to avoid the problems associated wear of cast iron wheels.

So hopefully these notes will help anyone else contemplating fitting tyres to an existing locomotive, or to the wheels of a new locomotive. I have included some pictures taken whilst preparing the wheels and tyres for Fred, in the hope that they may assist.

The first stage is to look and measure. Either by reference to the drawings or the existing wheels, establish the maximum diameter over the flange and the wheel width. You also need to establish the inner diameter of the tyre, this will occasionally be marked on the drawing, but will usually be identified by the step on the face of the wheel casting or failing that, the inner edge of the rim. You will now have the 3 critical dimensions, needed to obtain the material. But what about tools? Fairly obviously you need a lathe and it must be capable of taking the wheelset between centres, or with care, chuck and centre, having due regard for any crankpins. Ideally you also need micrometers, both internal and external; vernier callipers can be used but great care is needed to ensure you get the dimensions right! If you are fitting tyres from new, then they will be fitted to the wheels before mounting so the need to be able to support the set between centres is no longer relevant.

So to the material. There are essentially 3 options; the first being thick walled tube, but finding the right size and someone prepared to cut some slices from it may not be easy; the second is to get sawn blanks, but these need to be either drilled and bored out, or trepanned out to make them into rings; the third is to get laser or flame cut rings. The size you require will be based upon the dimensions you obtained earlier but you need quite generous machining allowances; with approximately 2mm for each commercially sawn surface (blanks or thick walled tube); for laser cut, again 2 mm, not because of accuracy, but because of heat effects, this being even more significant with flame cut, where at least 3-4mm should be allowed for each surface, and do not forget that even flat plate will need about 2mm to get rid of surface scale and imperfections. A word of warning about thick walled tube, the bore can be appreciably eccentric with the outside, so allow a couple of millimetres for this! As for sources, local to Plymouth, Woodberry Chillcott will do sawn blanks and flame cut rings, Plymouth Metal Centre (Avon Steel) may also be able to do likewise.

So whilst you wait for those lovely bits of steel to arrive, it is back to the drawing board. The section of the tyre you will need to produce, is as in the sketch below. At this stage, the embryonic tyre that will be produced should have an outer diameter that is 1 or 2 mm over the finished tread diameter, with a distinctly oversize flange. These must be finished to size after fitting as they will change size during fitting. However the critical dimensions to be established, are the seating diameter of the tyre and the wheel rim width. This diameter is rarely given on a drawing, as the assumption is made that tyres will not be fitted, so a compromise situation has to be established. As a guide, I would suggest that the tyre should represent 35% – 45% of the total thickness of the rim and tyre. A thin tyre is unlikely to burst (just have a shorter life), whilst a thin rim could fracture if an impact occurs, but the tyre must be rigid enough not to distort excessively during machining. If the wheels do not have an identifiable rim (eg. disc wheels) then the equivalent diameter will be the inner tyre diameter as identified earlier. The wheel rim width may be indicated on the drawing separately from the total tyre width but may have to be inferred from the castings, the difference between the total tyre width and the rim width being the flange on the face of the tyre, which in 5” gauge (standard gauge stock) will be about 1mm thick or slightly less. You should now have the dimensions for the tyre, being the diameter of the tread, the thickness of the flange (not normally critical at this stage), the total width of the tyre, and the 2 critical ones of the diameter of the wheel seat and the depth of the recess to accept the wheel rim.



The most important thing to remember is that the tyre has to be shrunk on to the wheel such that this fit will hold the tyre on the wheel. So the wheel seat in the tyre must be made smaller than the corresponding diameter of the wheel. The amount of this difference in size (interference fit) should be between 1 and 1½ thousandths of an inch per inch of diameter. Thus if the nominal seat diameter is 4” and the tyre is bored to 4.000” diameter, then the wheel should be 4.004” to 4.006” diameter (I would err towards the larger size). You can see now why micrometers are most desirable! If you prefer to work in millimetres then it is still a matter of multiplying the diameter by 0.0015 to determine the interference.

So to start cutting metal! I would always prepare the tyres first, as it can be easier to machine the wheels to accept the tyres, than reverse. One of the first jobs is to clean up any flame cut edges if this is relevant or to trepan out the centre if you are using sawn blanks. If you have never come across trepanning before, it uses a tool similar to a parting tool with a heavy clearance angle on the left side, driven into the face of the steel blank. Obviously care needs to be taken to ensure the clearance angles are adequate, as it will cut a circular groove. Also the process can be carried out from both faces in order to keep the tool (and hence the depth of cut) short. At least you are left

with a disc from the centre, which can usually find further use. And so to preparing the actual tyre. There are a number of ways to approach this task, but I would suggest the following sequence, being the one I use.

Start by holding a ring by its inner diameter, leaving the outer face clear of the chuck jaws. Face off the ring, sufficient to get a clean surface, although this is the face of the tyre, it will be finished later. Next reduce the tread portion, leaving it over diameter by 1-2mm and under width by a similar amount leaving the flange appreciably oversize; these will also be finished to size later. This ring can now be removed and the next treated similarly and so on until all are done to this stage. The next stage is to hold each ring in turn by the tread just cut, taking care to ensure it is held securely, but without excessive pressure to create distortion. Start by boring the wheel seat diameter, taking care to get the diameter correct and leaving the flange on the face of the tyre(at the bottom of the bore), over thickness by about 1mm, finish this using a tool with little or no tip radius to keep the corner of the recess square. The remainder of the boring can now be completed, by sizing the inside of tyre face. Finally face off the back of the tyre, such that the depth of the recess is the same as the width of the wheel rim. This completes one tyre, apart from removing all the sharp corners, then it is simply a matter of repeating this for all 4,6,8 or however many tyres are required.

Now that you have completed your tyres, they need to be measured. Measure the bore of each tyre at several points, checking for any abnormal measurements, then take the average and actually write it on the tyre, at least you then know the size of each one! Also record the depth of the recess. Now the required wheel diameters can be established, being the diameter of the tyre bore plus the interference amount, make a list of these as well.

Now it is time to start machining the wheels! Assuming they are on their axles mount the set between centres and verify the concentricity of the journals. If they are not acceptable, or no centres are present, then remedial action will be required before work can start (it is probably worth doing this earlier in the proceedings). If the wheels happen to be new, then this work can be done with them on whatever mandrel you are using. Firstly, reduce the diameter, removing any existing flange and tread, until the desired diameter is reached; keep checking as the diameter gets close. It is probably best to start with the largest target diameter first, so that a slightly heavy final cut need not result in a ‘scrapper’. Next face off the rim, to remove the ’cast’ tyre face, reducing the thickness of the rim to the corresponding tyre recess depth. Make sure you stop this facing a few thou smaller than the inner diameter of the tyre front flange to avoid incorrect appearances, particularly with balance weights. Finally take a chamfer between the diameter and the face, sufficient to ensure that it will clear any radius in the root of the tyre. Mark the wheel with its diameter, to ensure that it can be matched up with its tyre later. Continue until all the wheels have been machined and identified and finally match them up with their respective tyre, which at this stage will not fit!

Now for fitting the tyres! All solids expand when heated; OK, so water has not read the rules! But the amount always seems to be so very small you may wonder how a tyre could ever be fitted by this method. There was a small conundrum that circulated a few years ago, that asked ‘How long is the carpet in Concorde?’ the answer being that it depended upon how fast she was flying, for at full speed, the skin friction heated the airframe such that it grew by almost 1 foot! So back to our case; the coefficient of expansion for steel, is quoted as 0.00000633/°F or 0.0000114/°C which means that for every 100°C a 1” piece of steel will expand by approximately 1 thou, remember that a hole will expand at the same rate. Thus to achieve clearance over the interference on our wheels, it should be sufficient to heat the tyres to 200°C, but the clearance would be so slight that we need a bit more, so we need to heat the tyres to 3-400°C to ensure that they will fit!

However a slight deviation before we fit the tyres! Although the shrinkage (hoop stress) is considered more than sufficient to permanently hold the tyre in place, the rolling action can cause fretting and other strange effects at the wheel/tyre interface, so a secondary form of fixing is always

applied. There are a number in use in full size practice, but many of these require the use of high pressure rolling facilities so the easiest for us to adopt is riveting. This involves putting a number of rivets through from the face of the tyre flange and the wheel rim to the inside. These being countersunk on the face and rear of the wheel and machined flush when the tyre is being finished. For scale 5” gauge stock, 1/16th diameter (annealed welding wire) at every second or third spoke is quite successful. For disc wheels 6 or 8 will be appropriate and of larger diameter if possible.

So to fit the tyres. Support a tyre face down on 3 firebricks, such that there is clearance inside and below for any crankpins or other obstructions. Have the corresponding wheel close at hand, but away from the hearth area. Heat the tyre gently and evenly until you are sure it is up to temperature. Any hint of redness means you are there. Keep the heat on for a minute or so to ensure that it is at an even temperature. Remove the heat and promptly lower the wheel squarely into the recess; there should be adequate clearance, so at any hint of trouble, lift the wheel (a small hammer can help) and start again. Once the wheel is seated, walk away and get a cup of tea (or whatever you prefer). Leave it all to cool for at least 20 minutes. And repeat for the rest of the wheels.

You should now have your wheels or wheelsets ready for final machining. But first that ring of rivets as secondary securing. This is a relatively simple matter of carefully drilling, countersinking and riveting each wheel in turn. If you are working on new or dismounted wheels, then such rivets need to be cleaned off, before returning the wheel to the backplate for final machining. If the wheels are mounted, then the rivets can be tidied during the machining. As a ‘last resort’ if there is any doubt about the security of a tyre, then a ring of socket grub screws can be drilled and tapped into the wheel/tyre interface from the rear, securing each with a little ‘loctite’.

And so to the final machining; this is a matter of bringing the tyres back to the intended dimensions as specified on the drawings. The only considerations being that you are machining steel and not iron, so chatter is a greater risk; also the diameters must be matched with greater care, as the wear resistance is greater, so a mismatched wheel could cause more problems. Additionally correct (conical) profiling is more relevant, once again due to the greater resistance to wear.

And so for the sake of a few hours work, your wheels should be good for many hundreds of miles. Remember that even now tyre re-profiling is a regular activity on the main line and for certain classes, periodic tyre replacement is still needed, after all the South Devon Railway are doing this with great regularity!

A wheel casting showing the dummy face

Preparing the tread ona flame cut ring. The original surface can be seen on the inside of the

Starting to bore a ring

A pair of prepared tyres. One from the front and the other from the rear

Preparing a wheel casting to receive its tyre