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“Watch your weight”

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Don't be alarmed, not the weight of the engineer; I mean the weight of the engine. It is a curious fact of life that builders of engines for 5" gauge (and other model scales) take considerable pains in increasing the "natural" weight of their locomotive by adding "ballast" whereas their full-size counterparts spent their professional lives trying to shed weight (from their engines). Loads and speed steadily increased over the years and it's not surprising that more powerful engines were needed, this was done by designing an engine bigger than the previous one with

larger boiler and cylinders which naturally tended to weigh more. The rails the trains ran upon were a matter of some concern right from the early days when the short lengths of cast and wrought iron supported on stone sets were only suitable for very light axle loadings. Remember the stipulation of the Liverpool & Manchester Rly that contesting locomotives for the Rainhill trials were to weigh no more than 4 tons empty, say 5½ tons working (boiler ¾ full), about 3 tons axle load?

By the middle of the 20th century the use of heavy steel rail mounted in chairs at about 2½ ft spacing had pushed the limit to 20 tons per axle on main lines, with an additional 2 tons on special routes (the Kings carried a "double red" RA code on the side of the cab to indicate that they were restricted to just the two principal routes of the GWR), while many secondary lines could only handle the 17 tons of Class 4 engines. The limitations placed on designers by the Chief Engineers (civil) responsible for providing the permanent way caused all sorts of headaches such as undersized boilers (LNWR Claughton), weak frames and bearings (Derby 4F), miniaturised valve gear (SR Pacifics), absence of running plates (SR Q1, BRW 1500) resulting from the struggle to keep weight under control. Designers of miniature passenger hauling engines have quite the opposite task: how to put on weight (well, at least on their engines!)

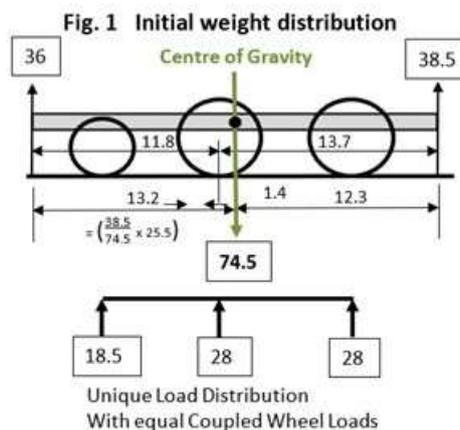
Why does this happen? Simple, we ask our engines to pull extremely heavy trains. Consider a 5" gauge dead scale 1¼" to the foot model of an LMS Class 5MT, just like Stanier's but reduced by a factor of 11.3 in all directions, its volume is reduced to a 1440th and so is its weight if made of the same materials (which it pretty well is). Each full-size ton becomes 1.6 lb of model, so the 72 tons reduces to 115 lb. In practice our models are about 20% overweight due to thicker frames and boiler plates with cylinders made from solid castings or blocks. A heavy Sunday afternoon load of driver plus 5 adults on two trolleys turns out at about 1200 lb, equivalent to 750 tons that have to be pulled up a bank like Shap. This is something that wasn't done on the LMS but it regularly happens in "5 Inch World". The required equivalent DB (drawbar) pull of 25 lbf is not too demanding, (requiring a Mean Effective Pressure of only 35 psi) but to grip the rail the coupled wheels need to be knurled, unless the model has been stuffed with lead to get over 50 lbf on to each coupled axle. This is why extra weight is needed, and our PW Engineer lets us get away with

it because the track is built to take trolleys loaded to 600 lb producing an axle load of 150 lbf so the engine is a featherweight in comparison.

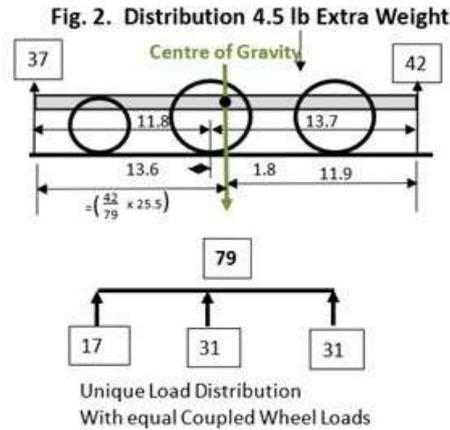
Not too long ago I carried out a lead stuffing exercise on my 5" G Whitworth, an engine which being a Victorian 2-4-0 is a rather difficult case to deal with. The prototype has the usual weight distribution for a three-axle engine of that era in which everything turns out hunky-dory with about $\frac{1}{3}$ of the weight on each axle but, as I suspected at the design stage of the model, the small version suffers from the usual nose-heavy syndrome. In fact, it is rather worse than usual as the cylinder block has inclined port faces with triangular steam chest, all made from heavy GM castings and located at the very front of the frames. The balance from the boiler is feeble as it is of slender proportions and placed well forwards with a very short smokebox. I did the usual thing and fabricated the drag box at the back from steel plate into which I hammered layers of sheet lead, it is a bit small but it finally weighed in at 7 lb thereby providing some balance to the cylinder block up front. There was nothing else to do at that stage other than to hope it would be alright in the end.

With the engine in its final stages of construction it was time to see how the weight distribution was coming out, nothing too difficult, just the dry weight and where the centre of gravity (CoG) lay, all done with a bit of wood packing and the bathroom scales. The engine is supported on packing on the bench under the front beam and drag beam in turn while the opposite end is lifted while standing on the scales. The engine's weight at each end is found by subtracting one's own weight from the readings on the scales, noting down the result, and quickly forgetting own weight. Fig. 1 shows the result: the front was 36 lbf and the back 38.5 lbf so the engine weighed in at 74.5 lbf overall but as the rear figure was bigger it meant the CoG lay slightly towards the rear in the proportion of $38.5 / 74.5$. Obviously the CoG will always be somewhere near the middle, and for a model 0-6-0 exactly where is not that important, but it is for a 2-4-0 which needs a decent proportion of the load taken by the coupled wheels.

There is a general belief in the modelling fraternity that the axle loading of engines can be sorted out by merely adjusting spring compression, but I ceased to subscribe to this view some time ago after writing mathematical equations that can calculate the loading based on information about the centre of gravity and spring rates. Some weight can be shifted between axles using spring adjustment, but the effect is very limited and the only real way to fix things is to get the CoG in the right place (see footnote). With a 2-4-0 there is only one spring adjustment that gives equal loading of the coupled wheel axles and for my engine it was 28 lbf on each, leaving $18\frac{1}{2}$ lbf on the leading axle. An adhesive weight of only 56 lbf is a bit limiting even for a Victorian engine and I decided to take advantage of the rectangular panels surrounding the rear wheels, effectively square splashers, and fill the upper corners with lead. As on previous occasions I shied away from pouring molten metal and instead spent a day cutting shapes from surplus flashing sheet, hammering them into the spare space and finally putting in small screws to hold them in place. I managed to work in a bit over 2 lb per splasher and then checked out the weight distribution.



As can be seen in Fig 2 the overall weight increased by 4½ lb to 79 lb and the CoG moved back by 0.4". This is not a lot but the equal loading on coupled axles increased to 31 lbf and 1½ lbf came off the leading axle. So, by adding 4½ lb of ballast the adhesive load increased by 6 lbf. Quite a useful exercise in seeing how the position of the centre of gravity is critical in obtaining a good weight distribution. Weight watching is definitely worthwhile.



Footnote: The LMS 8F 2-8-0 carries a boiler slightly different from the 5MT 4-6-0, the barrel is about 18" shorter and the boiler was moved forward so as to shift the CoG that way and obtain more even axle loads. I leave you to guess why Halls and 28xx 2-8-0s of another railway both carried No.1 boilers