Draft 1 July 2012

A discussion on design practice for side play in model locomotives.

In the dim and distant past, steam locomotives were designed to go around all sorts of curves, but the figure most often noted is that they should all have been able to get around a 4.5 chain radius curve at a dead slow speed. The first thing we should ask ourselves is 'where does this figure come from'? While it can be read as a valid starting point, is there any historical evidence to show this was an accepted figure for all UK built steam locomotives.

Evidence to the contrary as follows (but no access to original records)

- GWR seemed to accept that 5 chains was a suitable minimum with 4.5 chains if pushed.
- GWR 4200 - 6 chains normal or 5 chains dead slow
- GWR 2 cylinder locomotives - a minimal figure of 7 chains normal or 5 chains dead slow
- GWR 4-6-0s were built to 8 chains normal or 7 chains dead slow
  but a King needs 8 chains dead slow!

Even current heritage railways can have problems with curves, one curve at Newbridge on the NYMR was recently increased to 6.5 chains (no further details).

Back in the late 50s, I was sat on the old A14 just north of Huntingdon station with my jam butties and a flask of tea and spent a happy hour watching the staff trying to get a 9F out of the west side shed. The squeals must have been audible miles away. It took well over an hour and several bits were removed from the track (and hopefully later replaced) before it escaped.

However, for the purpose of this exercise, let's take 4.5 chains as a starting point. 4.5 chains is 299' which in 4mm scale is 1196 radius.

The famously infamous Versine Approach

And immediately my spell checker has asked "What's a Versine".

From Wikipedia - "The **versine** or **versed sine**, versin(ϑ), is a trigonometric function equal to $1 - \cos(\vartheta)$ and $2\sin^2(\frac{1}{2}\vartheta)$. It appeared in some of the earliest trigonometric tables and was once widespread, but it is now little-used." Apart from railway modeling, that is.

Let us consider the case for an 0-6-0, just to keep things simple for the moment, with 6' 8" diameter wheels on a 7' 3" wheelbase.

Let us also consider a scaled down wheel profile based on the prototype where the effective flange depth is 1/2" (Genzel). With the wheel set standing centrally on the rails there is 5/16" clearance between each flange and the rail. On the 4 mm model, the flange clearance then becomes 2 x 5/16" = 5/8" or 0.208 mm.

And finally, let us take the flange depth of 0.38 mm from the Scalefour Society Digest, P4 Track and Wheel Standards.

The flange length is given by $C = 2\sqrt{(r^2 - d^2)}$

$= 2\sqrt{(40.38^2 - 40^2)}$

$= 2\sqrt{(1630.5 - 1600)}$
$= 2\sqrt{30.5}$ = 11.4 mm

The effective flange distance is therefore 11.4 mm, a CAD drawing shows the actual chord length very slightly under this - done just for confirmation.
The effective wheelbase for the specified wheelbase is therefore 29 mm + 29 mm + 11.4 = 69.4 mm.

In P4 with zero side play on the model, and assuming that the wheels are close to the prototype profile and with the leading and trailing wheels hard against the outer rail using the Versine formula, the minimum radius is given by (Genzel)

$R = C^2/(8 \times V)$ where
R is the radius
C is the effective wheelbase
V is the total flange clearance

$R = 69.4^2/(8 \times 0.21)$
$= 4773/1.68$
$= 2866$

Note again that this is the minimum radius for a model with no side play, just the flange clearance.

So where is the side play

A P4 modeller will feel that this is a radius too far, or too high, so let's just see what is needed to decrease it to a more practicable figure, but perhaps not one with a radius so small that it will cause further problems such as buffer locking on reverse curves (Genzel), after all these are big engines!

Starting with a 1250 mm radius, for the Class 8C used above, which is where the bogie starts to hit the frames (see Class 8 instructions Page 10).

This is simply $69.4^2 / (8 \times 1250)$ = 0.48 mm

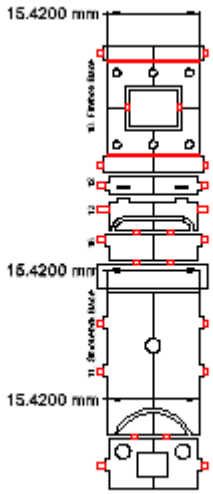
In tabular form :-

Radius	**Class 8C**	**Class 8**
1400	0.43 mm	0.39 mm
1300	0.46 mm	0.42 mm
1200	0.50 mm	0.46 mm
1100	0.54 mm	0.50 mm
1000	0.60 mm	0.55 mm
900	0.669 mm	0.61 mm

So much for the theory

The distance over the frames is a theoretical 16.17 mm which is a rounded up figure. This is less than some of the better kits but more than many, especially where generic frames are added under a standard body. As described elsewhere, there should be a minimum designed side play of 0.525 mm. Without resorting to the options described there, this is easily achievable, even removing the cusp to get rid of the way the etching works, or more especially to get rid of the parts where the etching has not done its' job, on the spacers will bring this nearer to 0.8 mm. Cusp removal is something I do automatically but perhaps do not emphasise enough in the instructions.

So what is achievable



The picture shows the etch of the P4 chassis parts as supplied to the etchers. The theoretical width with side frames at etch scale is still 15.42 mm + 2 x 0.375 = 16.17 mm. When we consider the cusp, the recommended figure for cutting beyond the design edge (Hollywood Foundry) is 15% of the metal thickness, which is 0.056 mm which means, assuming the cusp has been removed, a total frame outside width of 15.42 - (2 x 0.056) + 2 x 0.375 = 16.06 mm, or 0.11 mm lower than the theoretical width. Note that if the cusp is not removed, the metal at the centre of the etched component may be significant in places and cause problems later.

What this means is that the post-build measurements should always be better than the theoretical measurements. Allowing for measurement error the following results can be stated.

For two locomotives on the workbench (2 July 2012) and noting that the front wheel is set to have zero side play since it is behind the slide bars and that cusp on the spacers has been 'lightly' removed :-

Class 8C (6' 8" wheels), circular rim of Markits Horn Block removed and replaced by 0.15 washer

	Front	Centre	Rear
Chassis o/s frame	16.07 16.08	15.94 15.95	15.9 16.05
Side Play	Zero	1.0 mm	1.0 mm

Class 8 (6.0" wheels) Markits horn block as supplied

	Front	Centre	Rear
Chassis o/s frame	16.07 16.08	15.94 15.95	15.9 16.05
Side Play	Zero	0.8 mm	0.85 mm

So what about the bogie

In the instructions for the kits, it is noted that below about 1250 mm the bogie will hit the frames. It is interesting to note that the reason the frames were incurved at the front was to allow the bogie to pivot just that extra distance under full scale conditions.

All the new kits have a half etch semi-circular line on the inside of the frames since it has been recognised that some builders will not be comfortable with a 1250 mm curve. As noted in the kits, a radius under 1000 mm approximately will mean that the inside of the cylinders will be impacted by the bogie, necessitating the removal (usually by grinding) of the rear of the cylinders. Solutions I have seen (which were done a number of years ago on other Class 8 kits) include moving the pivot for the bogie rearwards to allow an easier swing.

Wheels

Wheels are an individual choice for modellers. It should be noted that wheels from Alan Gibson should have their rear boss removed as described in the series of articles printed in *"Scalefour News"* (and later in *"Forward",* the journal of the Great Central Railway Society. While this is explicitly stated in all the new kits (those released in early June 2012) this note was not included originally in the instructions for the Class 8.