LOCOMOTIVE COMPENSATION by Brian Clapperton, ABC Gears

Traditionally, model locomotives have been built with a rigid chassis. Some people looking for more realism have added horn blocks and spring suspension while others have been trying to improve running using compensation beams. Sprung and compensated options add complications to the model which in some cases have improved running but in others have produced less than satisfactory results. In this section we are going to look at compensation systems and some of the design features that influence its effectiveness. But first, perhaps it would be a good idea to look at the three main options and their good and bad points.

THE RIGID, SPRUNG & COMPENSATED CHASSIS

The three options generally used are the rigid, sprung and compensated chassis. First though, let us look at what the chassis has to do. The main requirements of the chassis are to:-

- Keep the wheels in contact with the track for good electrical contact.
- Distribute the weight correctly so that there is sufficient weight on the drivers for good adhesion.
- Provide stability on curves and uneven track.
- Stop wheels from touching other parts of the body and chassis to prevent electrical shorts.

The Rigid Chassis

The rigid chassis often works better than most people would think. Even a rigid chassis will flex a little and the flanges are still deep enough to prevent it derailing on reasonable track. As there is a fixed wheel in all corners of most locomotives, it is reasonably stable and by adding a little weight, there is usually enough contact for electrical purposes. Another advantage is that because the wheels are fixed, they are less likely to touch things and cause electrical shorts. Where this chassis fails is on weight distribution. This isn't a problem with a 0-6-0 but it could be critical with a single. This chassis does not allow all wheels to stay in contact with the track, especially on rough track.

The Sprung Chassis

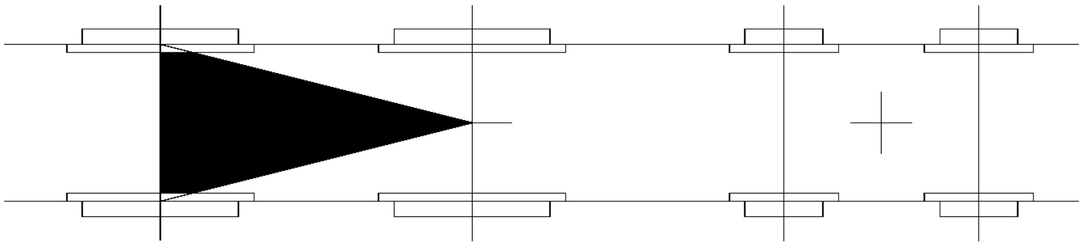
The sprung chassis does have the advantage that it is better able to keep all the wheels on the track at all times. It should be almost as stable as the rigid chassis. The biggest problem with this chassis is that it is very difficult to select springs of the correct strength and to adjust the tension correctly. Full size locomotives spend many hours on the weighbridge before they are able to perform satisfactorily. As a consequence, weight distribution can be very uneven leading to poor haulage. Because this system relies on horn blocks, there will be more moving parts to wear and wheels tend to move fore and aft as well as up and down requiring more care with clearances.

The Compensated Chassis

The compensated chassis is excellent at keeping all the wheels on the track all the time. Weight distribution can be designed on the drawing board by adjusting beam lengths and pivot points. Moving parts can be kept to a minimum by mounting bearings directly into the beams and as long as beams are made of relatively thin material, they will flex sufficiently to ensure that bearings can stay in alignment. The only movement for which clearance must be allowed is the up and down movement. If track laying standards are up to scratch, this can be kept to a minimum. In reality, this need only be 0.5mm each way. The whole purpose of compensation is to mount the chassis on three points like a three legged stool. This is very stable when the locomotive is standing still but things can change dramatically when the locomotive is travelling at speed. It is very important to take this into account when designing the chassis. This one point is the one that is often overlooked completely and can cause the downfall of the compensated chassis.

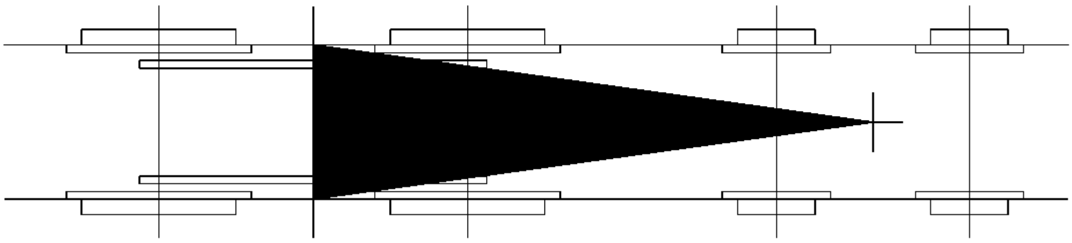
Let's Look at this 'Downfall'

To look at this in more detail, let's take the 4-4-0 locomotive. How often have we seen the back axle fixed and a bar resting on the front driving axle. Yes, it is a true three point suspension but the three points are very close to the back of the locomotive. To prevent the locomotive from falling over, the centre of gravity must sit within the triangle (see sketch), ideally in the middle of the triangle as this will mean that all the four wheels are carrying the same weight. This is going to be very difficult with this locomotive. All the space behind the centre of the triangle is taken up with the open footplate and the motor/gearbox unit in the back of the firebox. The smoke box is a long way forward of the triangle and working against us. If the centre of gravity is too close to the front driving wheels, not only will there be little weight on the rear wheels but we will be asking the front driving axle to prevent our locomotive rolling sideways on the curves. As the locomotive is resting on the middle of the front axle, we are not going to get any help from here. The rear inside wheel will lift off the track and the front outside wheel will drop until it comes to the end of its travel.



A Possible Solution

A better solution would be to rest the front of the locomotive on the bogie and to install a beam on each side, pivoted in the middle, between the driving wheels. In this solution, the triangle (see sketch) is much larger and so the locomotive is more stable. The weight acting on the rear beams is evenly distributed between the four driving wheels which is much better for pulling trains. As some weight is needed on the bogie, the ideal centre of gravity is very close to the front driving axle enabling more useful weight into the locomotive which will improve adhesion.



Beams Pivoted Away from the Middle

It is sometimes a good idea to pivot beams at a point other than in the middle of the beams. This time let us have a look at the 4-2-2 single, at first sight, this locomotive is very similar to the 4-4-0. We could rest the front of the locomotive on the bogie and use two compensation beams, one each side between the driver and the trailing wheel. We did say before that there would be the same amount of weight on each of the two rear axles. As the rear axle in this example is only a trailing wheel, it would be nice to transfer some of the weight on that axle to the driving wheel. We can do this by moving the pivot point forward. If we move the pivot point forward at the ratio of 1 to 2, the driving wheel will carry twice the amount of weight that the rear trailing wheel carries. The triangle becomes a little smaller but it does move forward and does not affect stability on curves. Also, the ideal centre of gravity moves forward which makes it much easier to get even more weight on the locomotive, and hence the single driver.

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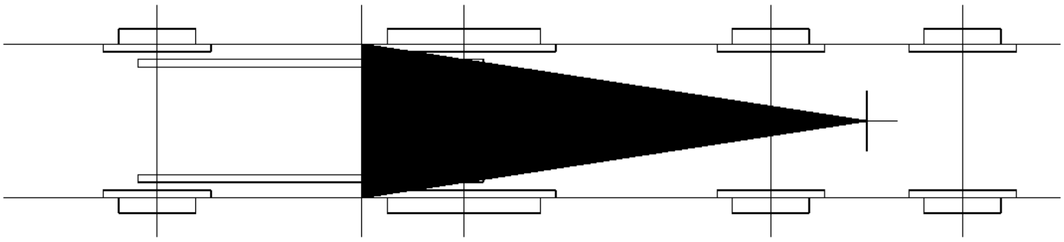
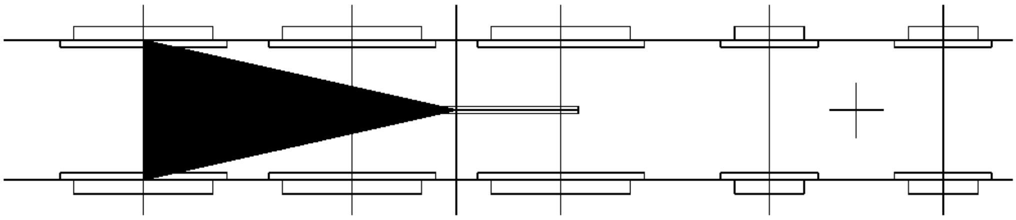


The 4-6-0

Let us also have a quick look at the 4-6-0. Many people fix the back axle and rest the compensation beam on the middle of the centre and front drivers. This is not a very elegant solution. It does make inside working valve gear difficult if you want to include this option. If we look at our triangle again, we see that although the triangle is quite long compared to our 4-4-0, it is too near the back of the locomotive and effects stability on curves.

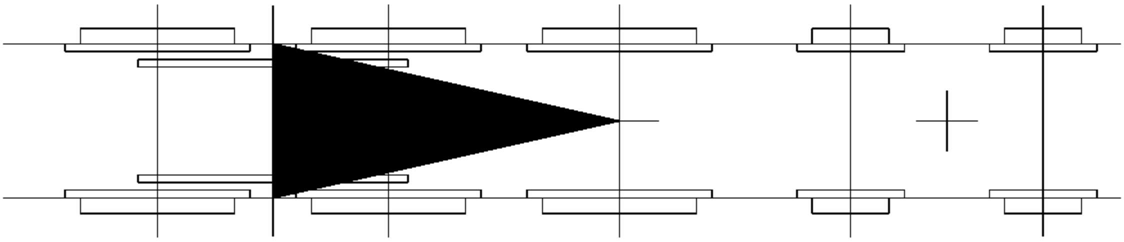


Here we can look at three possible solutions and their advantages and disadvantages.

SOLUTION 1

Move the Triangle Forward

One solution could be to allow the front axle to rock and place a beam either side between the rear and centre driving wheels. The triangle is about the same size but because it has moved forward, the locomotive will be more stable. The ideal centre of gravity is also moved forward enabling us to add more useful weight to the locomotive which improves adhesion.

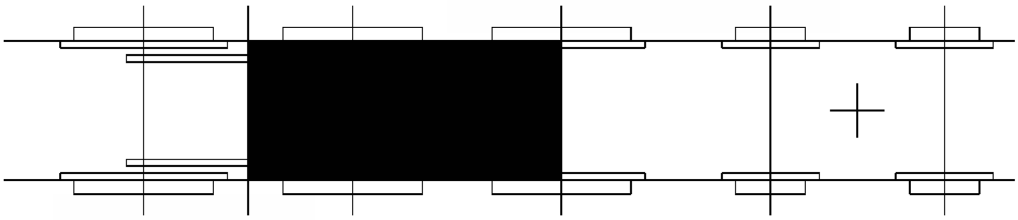


SOLUTION 2

Four Point Suspension

This is almost certainly going to be a controversial solution but has been included for you to make your own assessment and to make this section complete.

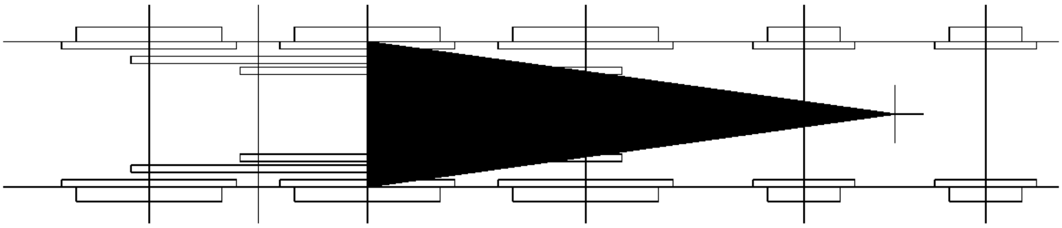
Four point suspension is achieved by fixing the front axle and placing a compensation beam either side between the centre and rear driving axles. The compensation purist will point out that this system sits the locomotive on four points instead of three. Before we reject this solution out of hand, let us look at its merits. The advantages with this system is that there is plenty of stability and the ideal centre of gravity is near the centre driving axle but it could be moved a little forward without effecting stability on curves. This means there is plenty of room for adhesive weight. The disadvantage is IT IS NOT a three point suspension system, therefore cannot guarantee that all six drivers will be on the track all the time. It will however be able to compensate for rise and fall in the track.



SOLUTION 3

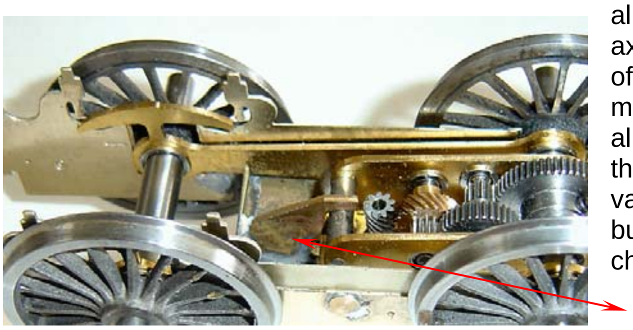
The 'ROLLS ROYCE' Solution

We saw with the 4-4-0 locomotive the advantage of sitting the front of the locomotive on the bogie. The 4-6-0 can also benefit from this idea but the beams become more complicated, we still need a beam between the front two driving axles but this time, the beam is pivoted on the second beam which is pivoted on the frame with the rear axle at the other end. By moving the pivot forward at the ratio of 1 to 2 this will ensure that the same amount of weight sits on all drivers. Our triangle therefore is quite long and towards the front, giving excellent stability on the curves. The ideal centre of gravity is also a long way forward giving added benefits for hauling heavy trains. The only slight complication with this system is that the rear beam needs to be pivoted above the centre axle so the beam will have to be curved.



The Motor/gearbox Unit

People are often reluctant to mount a motor/gearbox unit on a moving axle but this only means that a little more clearance is needed around the motor. It is however very important to allow the motor/gearbox unit to float, whether the axle is fixed in the chassis or not. It is very difficult to keep the two chassis bearings and the two gearbox bearings in perfect alignment when fixing the gearbox rigidly in the chassis, especially when the chassis flexes. Any alignment errors will effectively pinch the axle causing drag and premature failure of the gearbox. Most modern motor/gearbox units are small enough to allow a compensation beam beside them. The ideal restraining system will vary depending on the unit you are using but a type of fork in the middle of the chassis hooked onto the gearbox is one solution.



The fork should allow the gearbox to rock and move with the drive axle, the only restriction needed is to stop the gearbox rotating about the drive axle.

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Some Maths

So far we have looked at enough examples and ideas for most people. If we want to take things a little further, we could calculate what weight we want, where and how it affects the length of beams. To show what we can do with some Maths we are going to look at a 2-2-2 Single with a wheel base of 70mm and 70mm. The first thing we need to do is decide what the locomotive is to pull. This can be worked out by measuring the force needed to pull the intended train along or by one of the many formulae that have been published over the years. Just to come up with a number so we can continue, I am going to introduce my own formula which can be modified to suit your own requirements. The formula is:-

Tractive effort of the model in grams = Tractive effort of the full size loco in lbs divided by 100

If our prototype has a Tractive effort of 11,000 lb, our model will need a Tractive effort of 110g

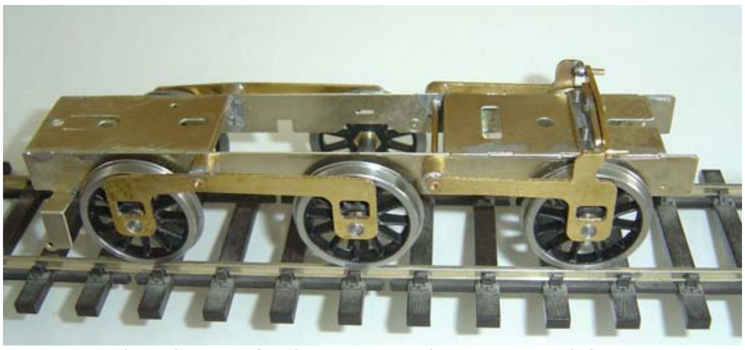
Because the coefficient of friction for steel wheels on nickel silver track is about 5, we need 5 times this weight on the driving wheel which is 550g. The leading and trailing wheels need to carry some weight to keep them on the track and to steady the locomotive. Experience has taught me that this needs to be about 150g. From this we can see that the total weight of the locomotive needs to be:

150g + 550g + 150g = 850g

If the compensation beam is to be between the middle and rear axle and these wheels are 70mm apart, the beam obviously has to be 70mm long. Because we want 550g on the driver and 150g on the trailing wheel, the pivot needs to be moved forward to the ratio of 150:550. That means the pivot needs to be 15mm behind the drivers and 55mm in front of the rear trailing wheels.

To ensure that the front axle carries 150g, we need to ensure that the centre of gravity of the finished locomotive is in the correct place. This we can calculate in the same way. The distance between the pivot point and front axle is 85mm (70mm + 15mm). If 150g sits on the front axle and 700g (550+150) on the compensation pivot, we can proportion the centre of gravity in the ratio of 150:850 from the pivot point. The centre of gravity needs to be 15mm in front of the pivot and 70mm behind the front axle. As our locomotive is symmetrical, it comes as no surprise that the calculated centre of gravity is over the middle axle.

The Tender

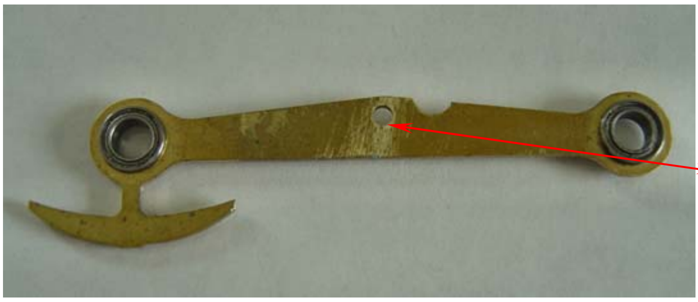


Not everyone compensates the tender as it is not really a part of the locomotive but a piece of rolling stock that always seems to accompany the locomotive. The only exceptions are when the tender is motorised or used to collect electrical current. There are a number of advantages to compensating the tender but let's look at some of the ways we can do it.

Many people fix the back axle and rest a beam on the middle of the middle and front axle. This system has a number of disadvantages. The first is that it uses some form of horn block which means more moving parts, wear and the problem of wheels moving into brake blocks. The second is that the bearings don't support any of the weight as it is all taken on the beam rubbing on the axle, which is a horrible way of doing it. The biggest disadvantage is one of stability. We have a heavy locomotive in front of the tender and it may well be coupled together by some form of bar. If the locomotive should become derailed, it is possible that the locomotive will sit on the coupling bar. If the pivot is too far forward, the weight of the locomotive will tip up and the tender top may well do damage as it hits the top of the cab. Moving the pivot forward will make the tender more stable. This will reduce the amount of weight carried on the middle axle but this will not adversely affect running.

We could also consider mounting the bearing into beams mounted each side. This would give us a four point suspension or we could allow the rear axle to rock. If we are feeling very adventurous, we could make the beams fit on the outside. This may mean that the pivot has to be some way above the axles but I have never found this to be a problem. The advantage of mounting the beams on the outside is that it is much easier to take the wheels out for painting and we can use much smaller bearings which will reduce drag.

Some Examples



Compensation Beam fitted with ball races. The beam includes a dummy leaf spring and a cut-out to miss the brake gear.

The beam pivots on the hole in the middle.

These 2 pictures show bogie beams pivoted on a stub axle in the middle of the bolster, this assembly is then screwed to the cosmetic frames. Notice the 2 rivet heads which the loco chassis rests on. The weight of the loco prevents the bogie frame from rocking for and aft but allows the bogie to rock from side to side.