

April 26, 1864.

JOHN ROBINSON M'CLEAN, President,  
in the Chair.

No. 1,113.—“On the Structure of Locomotive Engines for ascending Steep Inclines, with Sharp Curves on Railways.”<sup>1</sup> By JAMES CROSS.

A LOCOMOTIVE engine for ascending steep inclines in combination with sharp curves, should not only possess great facility for moving freely round those curves, but combine safety and steadiness when travelling at high speeds on straight lines; so as to enable the engine, which has brought its load across the plain, to traverse a mountain ridge and continue its journey on the level ground beyond. The other desiderata are large boiler power, in order always to command a full head of steam; and ample accommodation for fuel and water, so distributed as to give increased adhesion to the driving wheels without unduly loading them; thus a separate tender (itself no small load on a heavy incline) can be dispensed with and greater available haulage power or duty can be obtained. The ordinary locomotives are primarily adapted for running on straight lines, and although these engines do go round curves, it is only by a continual antagonism between the leading and trailing wheels and their superincumbent weight. The wheels try to mount the outer rail, by the frictional adhesion of their flanges, and the weight presses the flanges to the rail, which acts as a grindstone; while the engine itself moves round by a succession of jerks, every one of which represents a blow, to the framing, more or less severe, according to the speed and the radius of the curve. The cost of repairing the framework, axle boxes, guide blocks, &c., on long engines traversing sharp curves, is therefore a heavy item in locomotive expenditure. Steep inclines are generally worked by tank engines, and, for the reasons already given, a powerful tank engine of ordinary structure, if it carries fuel and water for a long journey, is, from its short wheel base, a source of serious injury to the permanent way; while if this evil be avoided, the engine can only carry a supply for short distances, and in many cases at a great disadvantage.

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<sup>1</sup> The discussion upon this and the following Paper occupied portions of two evenings, but an abstract of the whole is given consecutively.

Again, the torsion on the axles of ordinary locomotives when traversing curves is very great; the only means by which the tires of the wheels can adapt themselves laterally being their conical shape. This is not in itself sufficient, even on curves of large radius; and on curves of small radius, and on the multitude of deviations from the straight line caused by irregularities in the rails, it is altogether useless; and hence the rapid destruction of tires and rails. This mischievous friction, again, reacts on the haulage power of the long engine, so that many of the old four-wheeled engines are nearly equal in haulage power, on sharp curves, to six-wheeled engines, wherein the haulage power is reduced to a minimum, when the curves are combined with steep gradients. For this reason, locomotives are occasionally unable to start again after stopping on ascending curves, the wheels being rail bound; and it would seem, that for a line on sharp curves, a four-wheeled coupled engine, properly balanced, is much more economical than a six-wheeled engine, and is, to all intents, as effective.

An attempt to meet the foregoing requirements, and, as far as possible, to obviate the disadvantages named, has been made by building a locomotive fitted with Adams's radial axle boxes and spring tires. This was built as a passenger engine, and is not therefore cited as a specimen of a powerful engine for steep gradients combined with sharp curves, but as a specimen of a long-based engine passing freely round curves which are impassable to the ordinary engines of 15-foot wheel base, and as illustrating the principle which is believed to be the best adapted, by its simplicity and efficiency, for working all lines with sharp curves, with or without steep gradients. It is thought, that the results of the actual working of this engine will be valuable, as any reasonable amount of power can be provided in future engines.

The following are some of the principal details: There are eight wheels; the leading and trailing wheels are each 3 feet 3 inches in diameter, and are fitted with radial axle-boxes; the driving-wheels are each 5 feet 1 inch in diameter, placed immediately in front of the firebox, and coupled to a similar pair immediately behind it. Krupp's tires are used on all the wheels, with springs between the tire and the periphery. The distance from the centre of the leading wheel to the centre of the driving wheel is 7 feet; from the centre of the driving wheel to the centre of the coupled wheels, 8 feet; and from the centre of the coupled wheels to the centre of the trailing wheels, 7 feet. The rigid wheel base measures 8 feet. The total wheel base is 22 feet. The total length of the framing is 31 feet  $\frac{3}{4}$  inch. The weight on the leading wheels is 7 tons 15 cwt.; on the driving wheels, 11 tons

15 cwt. ; on the coupled wheels, 11 tons 5 cwt. ; and on the trailing wheels, 4 tons 10 cwt. ; so that the total weight is 35 tons 5 cwt. when empty.

The cylinders, which are inside, are 15 inches in diameter, with a length of stroke of 20 inches. The fire-box is 4 feet  $1\frac{3}{4}$  inch by 3 feet  $3\frac{3}{8}$  inches inside. The boiler is 10 feet 5 inches long, and 3 feet  $2\frac{3}{4}$  inches in diameter. The fire-grate is 5 feet by 3 feet  $3\frac{3}{8}$  inches. There are 121 tubes, each 10 feet 11 inches long,  $1\frac{7}{8}$  inch outside diameter, and  $\frac{7}{8}$  of an inch apart. The heating surface in the tubes is 620 feet, in the fire-box 67 feet : total 687 feet. The pressure is 140 lbs. on the square inch. The tank, on the same framing as the engine, holds 950 gallons of water, and the bunker carries 25 cwt. of coal. The foot-plate is covered with a cab. There are no peculiarities in the fire-box, boiler, or motion, though, it may be remarked, that this class of engine gives great facilities for the use of the long boiler, and hence for economising the heat of a coal-burning fire-box.

The novelty of the engine is in the radial axle-boxes, which allow an engine on one rigid framing, carrying both boiler and tender, to pass round extremely sharp curves with an easy gliding motion, while the great length, controlling all irregularities, makes the engine very steady at high speeds. The construction in effect reduces the real wheel base of 22 feet to 8 feet when passing round curves, this being the distance between the coupled wheels.

The radial axle-boxes are only a little larger than ordinary engine axle-boxes ; but, instead of being square to the framing, are struck with a radius which has its centre in the centre of the adjoining axle, giving, in this case, a radius of 7 feet, which the axle-box guide-blocks are curved to fit. The boxes are allowed to play laterally  $4\frac{1}{2}$  inches on each side, and the spring-pins, instead of being fixed immediately on the top of the boxes, are each fitted with a small slide or roller, so as to allow the boxes to traverse freely. It will be at once seen, that the latter, though of a different shape, are still only axle-boxes weighing  $3\frac{1}{2}$  cwt. each, and that the only additional parts added to the engine are the spring-pin rollers. This simplicity so completely answers the desired end, that it is claimed as one of the best features of the new engines. The action of the axle-boxes is as follows :—On entering a right-hand curve the flanges of the leading wheels draw the boxes to the right, the framing remaining as a tangent to the curve ; and, as the axle-boxes are themselves curved, the result is to bring the axle on the right-hand side nearer to the driving wheel, and to push it on the left-hand side further from the driving wheel. The trailing axle, in its turn, takes a similar position, and the leading and trailing axles thus become radii of the curves they are tra-

versing, and keep their flanges always parallel to the rails; and the boxes, moving freely from right to left, adjust themselves to the multiplicity of short S curves caused by irregularities in the rails. By looking over the side, while the engine is moving at high speeds, the boxes may be observed to move with an incessant lateral vibration, while the frame remains steady (thus showing the number and amount of blows which the frame and rails receive in ordinary cases), the friction, in passing round curves, being limited to the coupled wheels, or 8-feet base. This 8-feet rigid base is, however, again greatly eased in passing round curves, by the use of the spring tires, which admit of a slight lateral motion. These tires also give a better grip on the rail, by slightly flattening under the weight of the engine, and thus presenting more surface for friction. As a proof of this, a train of wagons was placed on a curve of 450 feet radius, with a rise of 1 in 78, and two engines—identical in every respect, (except that the wheels of one engine had spring tires,) worked at the same pressure, and driven by the same man—were successively attached to it, when the one with spring tires brought out 15 wagons, and the one with ordinary tires 13 wagons. This result is confirmed by the working of all the engines fitted in the same way.

This engine was completed in the first week of November, 1863, and has been since running regularly, taking its turn of duty with passenger trains, or coal trains, or as a shunting engine, and about the numerous works connected by sharp curves with the St. Helen's line. The motion round curves is free from all jerking, and on straight lines the speed is more than 60 miles an hour, either end of the engine being first, without any train behind to give steadiness, and the motion is so smooth that it has only been by taking the actual time, that Engineers have convinced themselves of the fact of the speed exceeding 40 miles an hour. It was built to traverse curves of 200 feet radius. This it does with the greatest facility, and has regularly worked the passenger trains round a curve of 1,000 feet radius, going directly off the straight line by a pair of facing points, at a speed of more than 30 miles an hour; and it has gone round a curve of 132 feet radius. It has also run a train of twelve passenger carriages, weighted up to 100 tons, exclusive of its own weight, at 60 miles an hour on the level. From the advantages it possesses over ordinary mixed engines for weighting the trailing coupled wheel, it, without difficulty, on a wet slippery day, started and took this load up a gradient of 1 in 70, drawing seven of the carriages with a load weighing 72 tons 5 cwt. up a gradient of 1 in 36, round a curve of 440 feet radius; and coal trains of 250 tons are worked over long gradients of 1 in 200 with the greatest ease. It is evident,

then, that engines on this principle, affording facilities for the use of high power in hilly countries, are peculiarly adapted for metropolitan lines, where sharp curves are a necessity (being equally safe whichever end is foremost), and are also well suited for light lines in India and the colonies. It may likewise be remarked, that carriages and wagons on this principle would carry heavier freights, with a saving in the proportion of dead weight, while their friction round curves would be less than at present.