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A Study of the Mechanics of Curve Resistance.

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This is a subject that the writer has been interested in for a great many years, and as chairman of committee 16, Economics of Railway Location, American Railway Engineering Association, he has had occasion to study several theories on this subject, even to the theory that curve resistance was caused by the friction between the inner wheels and the inside rail of the curve, on account of the obliquity of traction. The majority of the theorists, however, give centrifugal force the center of the stage as one of the main factors in this problem.

The Economic Theory of Railway Location, by A. M. Wellington (6th edition), states in paragraph 296, pages 283 and 284: "The coning now put in wheels is chiefly useful as a prospective provision for wear; and experiment shows that whether the wheels be coned or not, the tendency of **any rectangular wheel-base is to roll very nearly in a straight line.**" This statement appears logical, but unfortunately it is not entirely true, as the writer will try to prove further on. What Mr. Wellington said years ago is still true (paragraph 292, page 281): "Curve resistance has never yet been exhaustively investigated, and our knowledge is in several respects deficient." The late Mr. Wellington seemed to have the most accurate knowledge of the actual conditions of any authority that the writer has ever read; still, we cannot agree with some of his conclusions. For instance, paragraph 314, page 294, in speaking of the conditions that exist, as shown in his figure 31, same page, states: "The consequences of this condition of things are these: first, the disproportion in the diameter of the wheels; **hence the necessary longitudinal slipping, and hence the curve resistance is materially increased.** If the increase of radius of wheel be 3/16 in., the **extra distance slipped through** per station of 100 ft. by one wheel will be 1.16 ft." The writer believes, which he hopes to prove later, that the emphasized statements are exactly opposite to the facts.

Referring to the theory of centrifugal force in this problem, the writer believes that with track having anything like the correct elevation of the outer rail, this is a very minor factor, that as far as the action of centrifugal force on the car body is concerned the result is simply the placing of more or less weight on the outer rail. Centrifugal force, acting on the truck, may effect the problem to a slight degree.

The theory of obliquity of traction, of course, is absurd, for we have on all railways positive evidence that the flanges of railway wheels cut away the head of the outside rail, while the evidence is plain that there is no flange wear against the head of the inner rail. The writer has no doubt that this obliquity of traction has a slight effect on the problem, but that this effect is very small is proved by the fact that a locomotive will practically push as many cars as it will pull. In the first place, the obliquity of traction is forcing the equipment against the outside rail, in addition to the other force that makes the flanges run against the outside rail, while in the latter case, the obliquity of traction is pulling the cars away from the outer rail; therefore, if this force was of any great moment, doubling the effect, as in the cases mentioned, would be more apparent than it proves to be in actual practice.

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The writer is well aware of the fact that it is easier to tear down than to build up, and the reader will rightfully say: "What is the good of all this criticism unless we can get some constructive material in its place?" To this the writer will have to admit that he cannot offer any scientific formulae that will satisfactorily explain actual curve resistance as we find it in practice. On the other hand, the writer has never seen in print a statement of what he considers the real reason why all outer wheels of railway equipment exert a pressure against the outer rail on a curve. Wellington states it is the rigid rectangular shape of the wheelbase. Those who pin their faith on the centrifugal force theory would make you believe that the wheels press against either the inside or outside rail, depending on the elevation of the outer rail in reference to the velocity. This we know from experience and practice is not true.

The reason all wheels of modern equipment, regardless of degree of curve, speed of train or elevation of track (within reasonable limits) exert a pressure against the outer rail on a curve is the fact that **a revolving cylinder tends to rotate in a straight line perpendicular to the axis of rotation**; or to reverse this proposition, **to make a revolving cylinder move in a direction not parallel with a line perpendicular to the axis of rotation requires a greater force than the force necessary to rotate the cylinder in a straight line perpendicular to its axis of rotation.** If our wheels were manufactured with flat treads and vertical flanges, on account of their being fastened rigidly to the axle, we would have in practice our equipment carried on revolving cylinders, with a portion of the cylinder cut away, and if this were the case, the writer believes it would be possible to devise formulae that would correctly represent actual amount of curve resistance. The writer's ideas can be made clearer by reference to plate 1, figs. 1 and 2, which represents a 4-wheel rectangular truck, with wheels rigid on the axle, rigid wheel-base and flat tread. The smallest force necessary to move this truck is the one required to move it on a straight line, perpendicular to the axis of rotation of the wheels. The force necessary to move such a truck parallel to the axis of the wheels, would be the weight of the truck multiplied by the coefficient of friction between the truck wheels and the surface on which it was skidded. If we represent these two forces by y and x respectively, and assume that we have a power at B moving in a straight line CB, such as a locomotive on a truck, and that this locomotive was attached by a flexible rope or cable to the center pin of the truck at C', the connection being made by swivel, and other details so perfect that the truck would maintain the same relative position while it was being moved along line C'B', the trucks would take the position so that the tangent of angle (a) made by the cable C'B and a line parallel with the axis of the trucks passing through C' would be constant and equal to $\frac{y}{x}$ and the strain in the cable would be equal to $\sqrt{y^2 + x^2}$, and resolving this force C"B" into two forces, one parallel to the line C'B' and the other perpendicular to this line, we get the actual pull in direction C'B' equal to C"y", and the pull on the locomotive at right angles to the track is equal to C"x"; if we give a definite value to angle ϕ it would be easy to obtain actual values of x and y. Instead of allowing the truck to take the position indicated in fig. 2, if there were small cleats (R.R. and R'R') nailed on the flat surface on which it is assumed the truck is moving, as indicated in fig. 1, neglecting the amount of friction between the wheel and the cleat, the pull on the locomotive would be C"y" and the pressure against the cleats would be C"x". Now, instead of having a straight line C B, if we have a curve line passing through C, we could replace the two cleats