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TRACK PROBLEMS DUE TO HIGH SPEED TRAINS

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Our fast society cureates the desire for increasing train speeds to compete other transport modes. This paper discusses the influence of increasing maximum speed on the alignment, turnouts and capital costs. The unpleasant influence of centrifugal force which is developed when trains are passing on curved tracks made it necessary to take care of its alignment. The maximum speed should be defined as a function of cant, non-compensated centrifugal acceleration, and curve radius. For aerodynamic considerations, track centre spacing must be increased to avoid extra pressure on train sides. Turnouts must be studied in form of tangent switch rails, transition curve, small angle of crossings and movable frogs. Advantages and disadvantages of braking types must be discussed. Shoe, disc and rheostatic brakes are to be considered, and slipping problems caused by poor adhesion between wheels and rails have also to be discussed. The automatic train control system, laying and maintenance tolerances, and economic aspects are among the main points to be studied.

New graphical and analytical relations to evaluate the effect of increasing speed on cant, curve radius and on the non-compensated centrifugal acceleration are shown. Hopefully these relations can help the designer either in choosing the alignment parameters or to improve the alignment for increasing speed on curved tracks. Finally, important formulae, tables and set of recommendations are presented.

1- Horizontal Curves:

The running of trains over curved track is bounded up with certain geometrical characteristics of the track and certain kinetic characteristics of the operation, where the dynamic behaviour of rolling stock has an effect. The general practice in this field is to rise the outer rail, which is called cant, in order to compensate the centrifugal force caused by passing of train on the curve. Cant, centrifugal acceleration and speed are essential parameters on curve alignment. The theoretical value is given by the following formula:-

$$H_T = \frac{11.8 \times V^2}{R} \text{ .... mm} \qquad (I-1)$$

where; V = The design speed in Km.p.h.
R = The radius of the curve in ms.

According to the difference between train speeds, theoretical cant must be reduced to practical cant which may be taken from the following formula:-

$$H = \frac{8 \times V^2}{R} \qquad (I-2)$$

The maximum value of practical cant in many countries is used to be 150 mm, but others are beyond this limit, such as Japanese National Railways (J.N.R.) French National Railways (S.N.C.F) and German Federal Railways (D.B).

The non-compensated centrifugal acceleration arises according to the difference between theoretical and practical cant which is called cant deficiency. This acceleration can be determined, in case of standard gauge tracks:

$$a = \frac{H_T - H}{153} \text{ m/sec}^2.$$

where; a = non compansated centrifugal acceleration in m/sec^2.

It is found that the value of the non compensated centrifugal acceleration allow a suitable degree of comfort to the passengers at speeds of 200 Km.p.h, which amounts to 0.5 m/sec^2. Increasing its value has been achieved by making improvements in the suspension system of the rolling stocks.

Non-classic types of vehicles, such as pendulum suspension, are made having automatic compensation of the transversal acceleration on curves. The additional cant not obtained from rails will be assured by the vehicles themselves when running at high speed.

For this purpose the vehicles will be equipped with devices intended to keep the body constantly in position, so that the resultant centrifugal force and the weight will remain perpendicular, or very near, to the floor of the coach. In this way, the passengers will feel no sensation of loss of equilibrium. Therefore, the operating coefficient K may be determined as:

$$K = 12.96 \times \left(a + \frac{(H + \ )}{153}\right)$$

where: = the additional cant which is obtained from car body.

Other development is undertaken to reduce the height of the gravity centre of the vehicle body which increases the resistance of the vehicle body against tilting and overturning during passing on curves. The advantage of these suspensions is that they can be moved with high speed on curved tracks without any increase in cant or even in the curves radii.

The maximum value of speed on curve can be determined from the fundamental relation between maximum speed and radius of curve as follows:-

$$V = K \quad R \qquad Km.p.h.$$

wjere: L = the operating coefficient which depends on the gauge, the cant and the value of non-compensated centrifugal acceleration. In case of standard gauges and ordinary coaches operating coefficient can be determined from the following formula:-

$$K = 12.96 \times \left(a + \frac{H}{153}\right)$$

where; H = maximum practical cant mm.
a = non-compensated centrifugal acceleration in m/sec^2.

Thus it is evident that it would be possible to increase the maximum speed on curves by one or more of the following measures:-

1) Increase the maximum cant.
2) Increase the value of non-compensated centrifugal acceleration.
3) Increase the radius of the narrow curves.

For this propose important graphical relations could be reached to show the amount of increasing speed corresponding to increasing the cant (H), the non compensated centrifugal acceleration (a) and the curve radius (R) as shown in Figure

Figure ( ) shows the gain of speed corresponding to 0.1 excess in operating coefficient (K) and also to 100 m excess in curve radius (R).

From this figure the following remarks could be obtained

1) the gain of speed, due to increase (K) by 0.1, becomes greater with bigger radii.
2) the gain of speed, due to increase (R) by 100 m, becomes smaller with bigger radii.
3) for radii less than 2300 m the gain of speed due to increase R by 100 m is greater than the gain due to increase K by 0.1.
4) for radii greater than 2300 m the gain of speed due to increase K by 0.1 is greater than the gain due to increase R by 100 m.

2- Transition Curves:

The transition from straight track without cant to curved track with cant must be provided gently by transition ramp and transition curve.

The lengths of ramps also depend on speed, where the change in lateral and vertical accelerations should not exceed certain limits dictated by smooth riding considerations.

The following are the types of transition ramps and main features.

2.1. Straight ramp:

The geometrical characteristics of the transition curve with conventional straight ramp are that both curvature and cant increase are at a linear rate. Such a ramp is easy to be prepared and maintained, it can also by converted into other types of ramps, e.g. as S-Shaped or sinusoidal curve, by means of straightening and tamping machines.

2.2. S-Shaped ramp:

The geometrical characteristic of a S-shaped ramp is that curvature and cant assume the shape of two composite quadratic parabolas which can easily be marked out on the ground. Such a ramp can successfully be used for speeds up to 200 Km.p.h.

2-3. Sinusoidal curve ramp:

Such a ramp is considered the most ideal transition curve ramp from a kinetic point of view, where improvement in smooth running is noticeable. Sinusoidal curve ramp has sufficiently been used on Japanese Tokaido line for speeds of more than 200 Km.p.h.

2-4. Transition ramp length:

According to Japanese Tokaido line specifications, the length of the ramp, irrespective of its shape, is determined from the following formulas (taking the longer value).

$$L = 7.5 \times H \times V \quad ..... \quad m$$

or

$$L = 6.2 \times H \times V \quad ..... \quad m$$

where;

H = the cant deficiency in m.
H = the maximum cant. m.
V = the maximum speed Km.p.h.

The French recommendation is to fix the change in cant or cant deficiency in high-speed track at 40 to 60 mm/sec, but the value of 60 mm/sec. still corresponds to a sharp entrance into a curve considering the French recommendation, using the change in cant or cant deficiency of 40 mm/sec.

The adequate ramp length can be expressed as follows:- (taking the longer value):

$$L = \frac{H \times V}{\frac{40}{1000} \times 3.6} = 7 \times H \times V \qquad m$$

$$L = \frac{H \times V}{\frac{40}{1000} \times 3.6} = 7 \times H \times V \qquad m$$

3- Track Spacing:

The question of fixing the track centre spacing for high speed lines requires careful examinations. Those examinations show that the top of the train causes air compression which commences some 6 to 8 m in front of the vehicle and reaches a maximum close to the front of the vehicle. As the displaced air must flow backgords the there occurs a corresponding reduction in pressure. As the pressure wave moving along with the top of the vehicle must flow along the sides of a train running or standing on an adjacent track, it must cause a shock on the window panes of a magnitude which depends on the train speed and on the distance between the tracks. The pressure differential on either side of a window panes may lead to the destruction of the panes.

From Japanese National Railways specifications, it is found that the minimum distance between the sides of a passing train on high speed track amounts to 0.8 m, adding the width of car of 3.4 m, the centre to centre distance between tracks has been decided as 4.2 m.

Conclusions and Recommendations:

The following set of conclusions and recommendations are reached:

1) Increasing the maximum speed on curves can be achieved by one or more of the following methods:
   - rising the maximum cant
   - increasing the non-compensated centrifugal acceleration
   - increasing the curve raduis.

2) The following methods can be used to increase the maximum speed as:

Variable	Value of rncrease	Resulted increase in maximum speed
Cant	+ 10 mm	+ 2.6%
non-compersated cenrtrifngal acceleration	+ 0.1m/sec^2	+ 3.7%
Curve raduis	+ 100 m	+ 8.3%

3) To increase speed from 105 Kph to 160 Kph or from 160 Kph to 200 Kph the following table can be used:

Speed Kph		Cant mm		non		radius	
From	To	From	To	m/sec^2	m/sec^2	m	m
up to 150 mph		-	150	-	0.450	-	600
150	160	150	150	0.45	0.450	600	1400
	or	150	170	0.45	0.535	600	1200
	or	150	170	0.45	0.850	600	1000
160	200	150	150	0.45	0.450	600	2200
	or	150	180	0.45	0.535	600	1800
	or		180		0.850		1525

4) From the Kinetic point of view the sinusoidal transition ramp is prefered more than straight or S-shaped curves.

5) With track spacing of 4.00 m the stresses acting on the sides of two trains meeting each other at an speed of 200 Kph remain within the permissible limits.

6) The minin raduis of vertical curve must not be less than 6000 m.

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