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Rail Leveling Analysis of Turning Radius and Speed Train Passenger Cart

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ABSTRACT

Needs consumer will tool transportation train fast fire on time now has sue Railway Corporation for Upgrade service and comfort for satisfaction para para consumer use tool transportation this in activity everyday. Look importance needs consumer will comfort use tool transportation train fire, then Writer interested for discuss comfort in journey train specifically problem journey train fire with elevation rail in pass Bend moment drove. Analysis done from Railway Corporation with literature assistance regarding problem railway. Remember breadth existing problems on train fire, then Writer limit only on calculation point heavy carriage, the forces that occur, and balance carriage when turn without and existence rail elevation. From result analysis carried out elevation data is taken rail maximum by 110 mm, radius curvature, speed plan maximum 120 km/h. Generate speed data critical in bend without elevation rail, and speed critical in bend existence rail elevation.

INTRODUCTION

In the current era of globalization, it is clear that the need for transportation is increasing day by day in line with the accelerating rate of population growth, population mobility, state development and people's prosperity. One type of transportation that is widely used in Indonesia is land transportation which includes rail trains, motorized vehicles, and so on. Rail trains, which are usually referred to as trains, are a means of land transportation that has many advantages . At this time the train has several classes in each type of train, namely: executive class, business class, economy class. In accordance with the rapid technological advances, Railway Corporation also provides and manufactures quality carriages that have strength, balance and resistance to shocks and vibrations that occur when the train is running at high speed, with the aim of improving services to users of these mass transportation services [1-7].

The science of "Rail Vehicle Dynamics" is a branch of "movement" science which specifically discusses the movements of all kinds of rail vehicles that run on "steel roads" or "rails". This knowledge contains unique elements or problems specifically related to railway engineering, so therefore it requires a special discussion in a separate vessel. The starting point for explaining the motion of a rail vehicle along its path of motion is to assume that the vehicle's motion is unaffected by other motions or that it is free from interference [8-10].

The principles underlying the relationships that govern the motion of rail vehicles are Newton's laws of motion [11-15]. The tendency of an object to remain in its state of motion is called inertia. Any external medium that exerts a force on an object to change its state of motion, that is, to overcome inertia, will thus experience an equal and opposite reaction force generated by the object. Such a reaction force, produced by an object undergoing a change in motion, is called an inertial force.

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Rail Vehicle Movement Resistance

In accordance with Newton's law that the motion of a vehicle along its path of motion is determined by the forces acting on the vehicle [16]. Which can be seen by looking at the styles depicted in Figure 1. The X and Y axes are perpendicular to each other and lie in the horizontal plane. The Z axis is perpendicular to the plane of the paper. Let's say the weight of our vehicle is G which works parallel to the vertical axis.

If the vehicle is moving, experiencing a resistance of (F) and if it is accelerated by a force (f) which should be the resultant force about its axis, eventually the vehicle may change direction causing a centrifugal force (C). For example, the force that exists between the wheel flange and the outer rail in a bend. While the forces (M) and (S) include resistance forces.

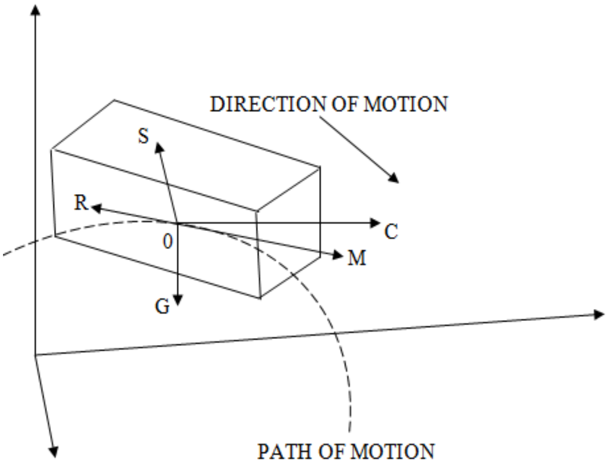

Figure 1. Reaction forces of moving vehicles

If the vehicle is moving, experiencing a resistance of (F) and if it is accelerated by a force (f) which should be the resultant force about its axis, eventually the vehicle may change direction causing a centrifugal force (C). For example, the force that exists between the wheel flange and the outer rail in a bend. While the forces (M) and (S) include resistance forces.

Prisoner Type

If a rail vehicle (train, or carriage) runs on steel roads (rails), then he will get a prisoner. According to the law, there is a reaction due to an action, so if there is a movement, there must be a prisoner experienced by the movement [17]. The same is true for rail vehicles that slide on steel roads. To be able to move forward on the rails, a force is needed to overcome these resistances, including:

1. Rolling resistance of the train/carriage = $F_{g,}$
2. Resistance of acceleration and carriage = F_{p}.

Loop Prisoner

Rolling resistance is the resistance experienced by rail vehicles caused by the friction of the wheels and rails, and friction due to the contact of the wheel flange on the inside of the rail head, while rolling on the rails [18]. Therefore, the formula for calculating the coil resistance on a flat and straight road is used with a coil coefficient of about: 2.5. According to the formula from "Strahl", the formula in table 1 is as follows:

Table 1. Specific Roll Resistance Formulas or Passenger Trains and Freight Cars

For 4 axle carriage	$= 2.5 + v^2/4000$
For 2 & 3 axle trains	$= 2.5 + v^2/3000$
For freight cars	$= 2.5 + v^2/2000$

If if the total weight of the carriage = G (kg), then taking into account the total weight of this carriage we will get the total coil resistance, which is equal to:

$$F_g = G \text{ x (kg)}$$

Where :

F_g = coil resistance (kg),
G = total weight of the carriage (kg),
coefficient of resistance.

Acceleration Acceleration Resistance

This resistance is the resistance of the rail vehicle that occurs when the train accelerates along the way, and this is especially true during the initial period of motion, in which case the acceleration force is considered a resistance [19].

So the formula for the acceleration is:

$$F_P = m \cdot a(N)$$

Where :

FP = Resistance to acceleration (N),
m = total weight of the carriage (kg),
a = Acceleration (m/s^2).

Road Safety In Arch

On the way through the peril arches are considered for safety, namely against the "danger of overturning". The movement of the train in passing through the curve as in Figure 2, gets an acceleration that is not used to accelerate the train, but only to change the direction of movement of the train, which is called "normal acceleration" or abbreviated as "a_n". The acceleration in the curve used to speed up the train is called the "tangential acceleration" or abbreviated as "a_t" [20].

So, if the speed of the train in passing through the curve is constant, then this means that $a_t = 0$, but the "normal acceleration" (a_n) is still there, that is, to change the course of the train, and its magnitude is:

$$a_n = \frac{v^2}{R} \text{ (m/sec}^2\text{)}$$

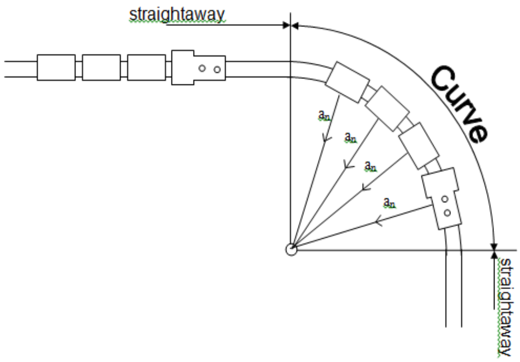

Figure 2. The movement of the train through the curve

where :

a_n = Normal acceleration (m/sec ^{2}),
v = speed (km/h),
R = radius of curvature (m).

Rail Raising In Curve

In the arch, the outer rail is slightly elevated relative to the inner rail. Raising this rail is called " *CANT* " (*railverkanting* (Bld)) which is nothing but intended to compensate or reduce the magnitude of the lateral shock acceleration caused by the free centrifugal force when the train/carriage is passing through a bend. The smaller the radius of the bend, the greater the required "rail elevation" [21].

As a result of the elevation of the rails in the curve, the permissible Arch Load Factor "B" in the arch can be greater, so that the maximum speed in the bend can also be increased. So the main purpose of the rail elevation is:

1. Increases the allowable "B" Arch Load Factor in that bend.
2. Increase the maximum speed allowed in the curve.

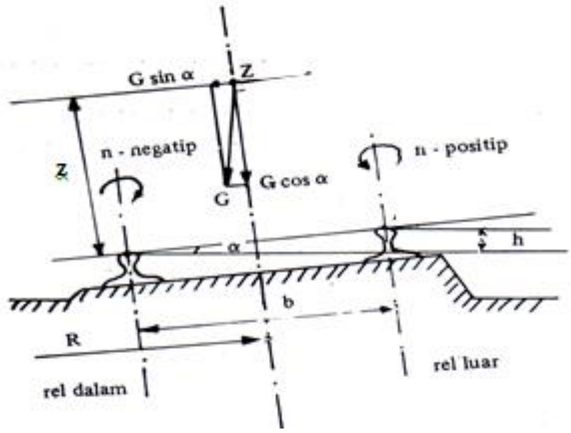

Figure 3. Rail elevation in arch

The effect of the elevation of the rail in the bend on the moment equation (see Figure 3) is:
We start from the equation:
C xz = G x b
(C.cos – G.sin) xz = (G.cos + C.sin) x b
The maximum price allowed is:
Sin = 0.1
Cos = 0.995 (rounded to safe = 1).
For security, the following prices can be calculated:
fc . cos = Fc
fc . sin = 0
(Fc. Sin can be ignored, because it is very small when compared to G).
So, the equation becomes as follows:

(C – G . sin) xz = G x b

$$\left(\frac{G \times V^2}{g \times R} - G \text{ x sin }\right) \text{xz} = G \text{ x b}$$

$$\frac{z.v^2}{g.R} - z.\sin\alpha = 1/2b$$

$$\frac{v^2}{R} = \frac{g}{2\frac{z}{b}} + g.\sin\alpha$$

If v is expressed in km/hour, then it must be multiplied by the factor : (3,6) ^{2} , so that the equation becomes:

$$\frac{v^2}{R} = \frac{(3{,}6)^2 g}{2\frac{z}{b}} + (3{,}6)^2 g \sin\alpha$$

If the price is taken: g = 9.8 m/sec ^{2} , then there are:

$$\frac{v^2}{R} = \frac{127}{2\frac{z}{b}} + 127\sin\alpha$$

We know that : v" = B $\sqrt{R}$ or $v^2 = B^2 \times R$

$$B2 = \frac{127}{2.\frac{z}{b}} + 127.\sin\alpha$$

From this it can be concluded that if "there is no" rail elevation, then this means that sinα = 0, so the magnitude of the "Curve Load Factor" is:

$$B = \sqrt{\frac{127}{2.\frac{z}{b}}}$$

Meanwhile, if "there is" a rail elevation, then the magnitude of the "Curve Load Factor" is:

$$B = \sqrt{\frac{127}{2\frac{z}{b}} + 127\sin\alpha}$$

Here it is clearly seen that with the elevation of the rail, the magnitude of "B" can increase, so that the critical speed at the bend can be somewhat higher. However, there is a maximum limit to the "rail elevation" in the curve, which is such that sin cannot exceed value = 0.1 (so : (max) = 5 ^{0} 45').

If sin > 0.1 , then when the train/carriage is stopped in the curve, the objects that are located on the floor of the train/carriage can all shift towards the inside. For the gauge width = 1067 mm as in PT. KAI, the maximum "rail elevation" at the smallest bend is:

$h_{(max)}$ = 0.1 x 1067 mm = 107 mm (rounded = 110 mm).

Normal Rail Raise

Normal rail height is determined by the formula [22]:

$$h_{norm} = 6 \times \frac{v^2}{R} \text{ (mm)}$$

Where :
V = Maximum specified bend speed (km/h),
R = Actual radius of curvature (m).

If the results of the $h_{norm\ calculation}$ with the above formula produce a price > 110 mm, then h_{max} = 110mm is still taken.

EXPERIMENTAL METHOD

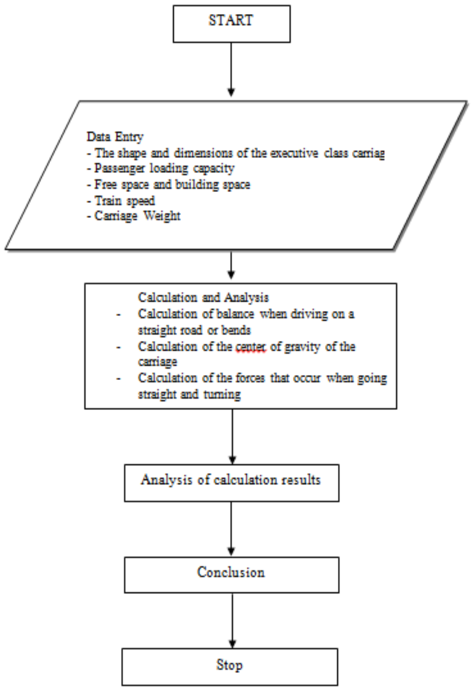

Figure 4. Work Diagram

RESULTS AND DISCUSSION

Balance When Turning With Rail Raising

Finding the critical speed in a bend by taking into account the bending load factor and the overturning safety factor and the radius of curvature of the rail elevation.

Then the calculation is obtained:

Formula :

$$v' = B\sqrt{R}$$

where :

v' = Critical speed (km/h),
B = Curvature load factor,
R = radius of curvature (m).

First calculate the bending load factor (B) of the rail elevation resulting from the moment equation, namely:

With sin = 0.1 ,

Formula :

$$B = \sqrt{\frac{127}{2.n\frac{z}{b}} + 127\sin\alpha} =$$

$$\sqrt{\frac{127}{2.1\frac{1778{,}33}{1067}} + 127.0{,}1} = 4.04$$

Then the critical speed is obtained with the elevation of the rail, namely:

$$v' = 4.04\sqrt{800} = 114.3 \text{ km/hour}$$

Table 2. Raising the rail at the bend

Bend radius (m)	Elevation at any design speed (mm)						
	120	**110**	**100**	**90**	**80**	**70**	**60**
100							
150							
200							110
250							90
300						100	75
350					110	85	65
400					100	75	55
450				110	85	65	50
500				100	80	60	45
550			110	90	70	55	40
600			100	85	65	50	40
650			95	75	60	50	35
700		105	85	70	55	45	35
750		100	80	65	55	40	30
800	110	90	75	65	50	40	30
850	105	85	70	60	45	35	30
900	100	80	70	55	45	35	25
950	95	80	65	55	45	35	25
1000	90	75	60	50	40	30	25
1100	80	70	55	45	35	30	20
1200	75	60	55	45	35	25	20
1300	70	60	50	40	30	25	20
1400	65	55	45	35	30	25	20
1500	60	50	40	35	30	20	15
1600	55	45	40	35	25	20	15
1700	55	45	35	30	25	20	15
1800	50	40	35	30	25	20	15
1900	50	40	35	30	25	20	15
2000	45	40	30	25	20	15	15
2500	35	30	25	20	20	15	10
3000	30	25	20	20	15	10	10
3500	25	25	20	15	15	10	10
4000	25	20	15	15	10	10	10

Table 3. Bend load factor and critical speed without rail elevation

B	Bend radius (m)	Critical speed (km/h)
	100	
	150	
3.53	200	49.9
3.53	250	55.8
3.53	300	61.1
3.53	350	66

3.53	400	70.6
3.53	450	74.9
3.53	500	78.9
3.53	550	82.8
3.53	600	86.5
3.53	650	89.9
3.53	700	93.4
3.53	750	96.7
3.53	800	99.8
3.53	850	102.9
3.53	900	105.2
3.53	950	108.8
3.53	1000	111.6
3.53	1100	117.1
3.53	1200	122.3
3.53	1300	127.3
3.53	1400	132.1
3.53	1500	136.7
3.53	1600	141.2
3.53	1700	145.5
3.53	1800	149.8
3.53	1900	153.9
3.53	2000	157.9
3.53	2500	176.5
3.53	3000	193.3
3.53	3500	208.8
3.53	4000	223.3

CONCLUSION

From the results of the calculation of the data above, it can be concluded that:

1. With a rail height of 110 mm and a rail width of 1067 mm, the radius of the rail slope is 0.1. This is the maximum bend radius value and must not exceed that price.
2. With the same radius (R) for increasing speed (v), the rail height (h) must be increased and or vice versa.
3. If the rail height (h) is the same, with the speed (v) increasing, then the turning radius (R) must be greater.
4. If the speed (v) is the same, with the radius (R) of the turn getting bigger, then the height of the rail (h) on the turn will be getting smaller.
5. With the value of the bend load factor (B), the radius (R), and the planned speed (v) at the bend without rail elevation, the critical speed through the bend is obtained. If the train speed exceeds the critical speed limit, the train will roll over.
6. With the value of the bend load factor (B), the radius (R), and the planned speed (v) at the bend with the rail elevation (h), the critical speed is obtained through the bend. If the train speed exceeds the critical speed limit, the train will roll over.

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