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A Study on Load Transfer during Acceleration and De-Acceleration on a Tri-Axle Vehicle

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Abstract: ***Transportation has been a major requirement in off high way conditions. Off highway vehicles are the one which has its gross vehicle weight greater than the on- highway vehicle and has to travel in different terrain conditions under laden and un-laden conditions. Hence the design, in which the vehicle has to be made from the conceptual stage of product development to the final production must undergo many design iterations to meet the desired needs. Finally, analysis of the same has to be performed in different analysis simulation software in order to realize the effect of loads on the vehicle. In fact, this paper describes the analytical methodology to analyze the effect of load on the vehicle axles (front axle and the rear tandem axle)during two conditions a) accelerating b) de-accelerating and a case study with graphs has been performed in order to realize the same.***

Keywords: GVW (gross vehicle weight), Tandem axle, stiffness, reaction force.

1. Introduction

A vehicle having more than two axles is called as the tri-axle vehicle. The rear two axles are called tandem axles as one axle follows the order. It is well known from the, Alembert"s principle which is an alternative form of Newton"s second law of motion, stated by the 18th-century French polymath Jean le Rond d"Alembert. In effect, the principle reduces a problem in dynamics to a problem in statics. The second law states that the force F acting on a body is equal to the product of the mass m and acceleration „a" of the body, or F = ma; in d"Alembert"s form, the force F plus the negative of the mass m times acceleration „a" of the body is equal to zero: F - ma = 0. In other words, the body is in equilibrium under the action of the real force F and the fictitious force -ma. The fictitious force is also called an inertial force and a reversed effective force. It is simple to calculate the effect of load on a two axle vehicle under a static condition. Rather in a tri-axle vehicle, the dynamic condition of the vehicle has to be considered in order to realize the aim of the paper as load analysis on a tri axle vehicle becomes statistically indeterminate. Hence the effect of the suspensions has to be considered in a tri-axle vehicle, in order torealize the load transfer during the acceleration and de acceleration conditions. There are many advantages of a tandem axle when compared to a single axle as it is more stable at highway speeds and have better suspensions. A vehicle with a tandem axle can be rated to carry a huge load when compared to single axle vehicle. In fact, it must be noted that design of the brakes should also be considered in order to act upon the axles. A tandem axle vehicle is less prone to swaying and bounce less in an off-highway conditions and hence more stability can be achieved. Rather, a tandem axle is usually more costly and also fuel economy suffers. The maintenance and components increases as the number of axles increases which also adds to the cost of production.

2. Case Study

A case study has been performed in order to realize the load transfer at different axles during accelerating and de accelerating conditions with dimensions of a vehicle. The nature of the graph is also plotted with respect to the same.

In this case study the GVW of a vehicle is considered to be 25 tons and the spring stiffness is considered to be 40 N/mm. The details of the vehicle as inputs are assumed to understand the purpose of the study. The grade of the road is considered zero i.e., flat road for better understanding.

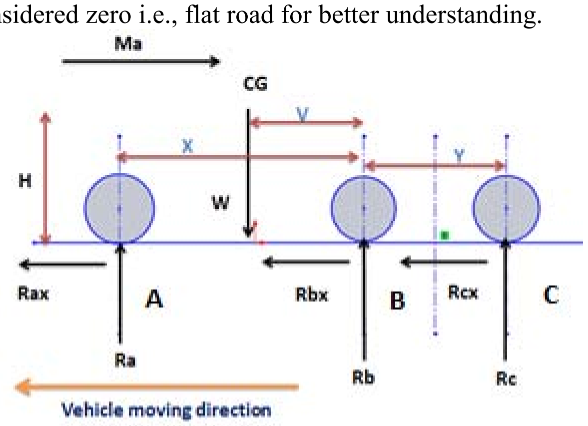

Figure 1: Dynamic condition of vehicle

Where,
h is the distance from ground to CG in mm
Rax, Rbx, Rcx are the horizontal traction forces
Ra, Rb, Rc are the vertical reaction forces acting on the wheel
X is the distance between centres of first wheel to the centre of front rear axle
V is the distance between CG to centre of front rear axle
And Y is the distance between the centres of wheels of the tandem axle
The specification of the vehicle is mentioned below in table 1

Table 1: Specification of vehicle

X	3190	mm
V	900	mm
Y	1500	mm
Ka	40	N/mm
Kb	40	N/mm
Kc	40	N/mm
H	1240	mm
W	25000	Kg
a/g	0-0.5	*
µP	0.81	*

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3. Methodology

For a body to be under equilibrium in a dynamic condition as shown in fig 1, there are three conditions to be satisfied,

∑M=0

∑Fx=MA

∑Fy=W=MG

Ra+ Rb+ Rc= W … (1)

Rax+ Rbx+ Rcx=Ma

Moment due to vertical forces about point CG

Ra(x) =Rb(V) + Rc(V+Y)

i.e., Ra(X) - Rb (V) +Rc (V+Y) = ∑Mv

Moment due to horizontal forces about point CG

h*(Rax+Rbx+Rcx)= ∑MH

∑Mv+∑Mh=0

Finally we get,

(X*Ra)- (v*Rb)-(V+Y) Rc+ WaH=0 …. (2)

Since a tri-axle vehicle is Statically Indeterminate, the effect of the suspensions has to be considered in order to realise the effect of load on front and rear tandem axle.

Zi =Fzi/Ki and

(Zi-z1)/ (Xi-X1) = (Zn-Z1)/(Xn-X1)

Hence Zi can be solved as

Zi= (Zn-Z1)/ (Xn-X1) + z1 which finally yields

(Fzi/Ki)- ((Xi-X1)/ (Xn-X1)*((Fzn/Kn)-(Fz1/K1))-Fz1/K1=0

For all i =2, 3, 4….. n-1

For a three axle vehicle, we get

(Ra/Ka)*(((V-X)/ (V+Y-V))-1) + (Rb/Kb)-(Rc/Kc)*((V-X)/ (V+Y-X)) = 0… (3)

Equations can be solved by the matrix formulation and is shown below

$$\begin{bmatrix}1 & 1 & 1\\ X & (-1)V & (-1)(V+Y)\\ (1/Ka)((Y/(V+Y-X))-1) & 1/Kb & (-1)(1/Kc)((V-X)/(V+Y-X))\end{bmatrix}\begin{bmatrix}Ra\\ Rb\\ Rc\end{bmatrix}\begin{bmatrix}W\\ (-1)Wah\\ 0\end{bmatrix}$$

$$\begin{bmatrix}1 & 1 & 1\\ X & (-1)V & (-1)(V+Y)\\ (1/Ka)((Y/(V+Y-X))-1) & 1/Kb & (-1)(1/Kc)((V-X)/(V+Y-X))\end{bmatrix}\begin{bmatrix}Ra\\ Rb\\ Rc\end{bmatrix}\begin{bmatrix}Wcos(phi)\\ (-1)h(ma+mgcos(phi))\\ 0\end{bmatrix}$$

If the grade of the vehicle is considered then the matrix changes as shown aboveWhere Ø is the grade angle in degrees.

4. Results and Discussion

The following results are obtained with the methodology explained above and the graph have been plotted to understand the effect of load transfer.

During Acceleration

FAW RAW

Table 2: front axle and tandem axle weight

FAW

A	Ra (In kg)
0.00	6170.39
0.10	5576.28
0.20	4982.17
0.30	4388.06
0.50	3199.84

RAW

Rb+Rc (tandem axle) in Kg
18829.61
19423.72
20017.83
20611.94
21800.16

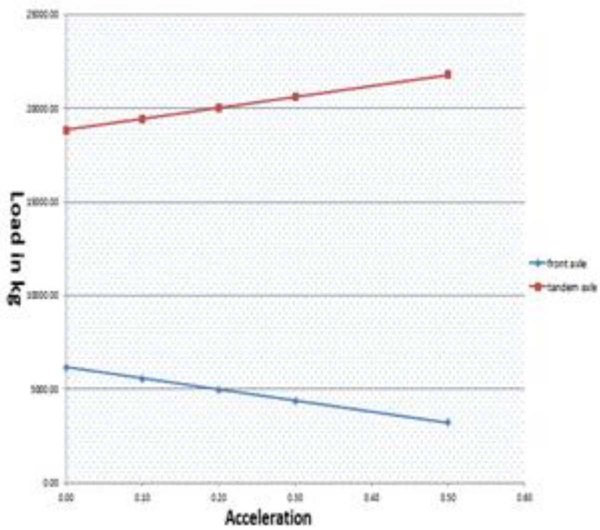

Figure 2: load transfer during acceleration in front and tandem axle

From the above fig 2 it is evident that, during acceleration, there is a load transfer in the tandem axle i.e., there is an increase in load in the rear axle than what it was under the zero acceleration condition or static condition. The design of the brakes must be performed by observing the behavior of the load transfer on the front and the tandem axle. From the figure above, it can be observed that as the acceleration increases the load on the tandem axle keeps on increases and the load on the front axle goes on decreasing. (Here „a" acceleration is considered as „a/g")

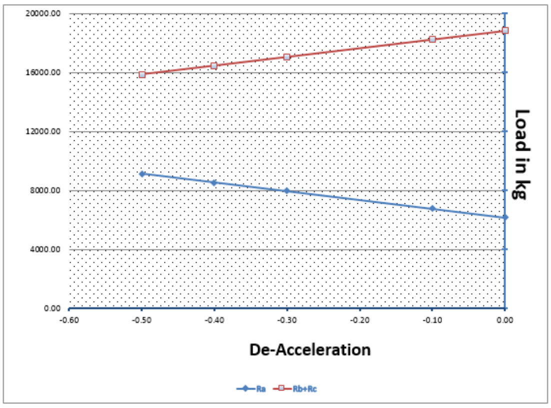

Figure 3: load transfer during de-acceleration in front and tandem axle

The role of brakes comes under picture during the de-accelerating conditions. From the above figure 3, it is evident that as the brakes are applied or de-acceleration takes place, the load on the front axle increases and load on the tandem axle decreases. Hence, it can also be concluded that the nature of graph of the brake force versus the acceleration for the front wheel traction force and rear wheel traction wheel follows the same nature of the graph. The acceleration can"t be more than 0.55 with respect to the inputs of the case study vehicle. The same graph plotted above can be used to realise the effect of de-acceleration.

References

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Author Profile

Sree Harsha Bharadwaj Hotur received the B.E. degree in mechanical Engineering from BIET Davangere under Visvesvaraya technological university in 2014 and presently pursuing M. Tech in NIE, Mysore and has a publication in an international journal- based on the title "entrepreneurship".