Design and Fem Analysis of Tractor Trolley Braking System

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ABSTRACT
Tractor trolleys are widely used in rural India. The major transport material and labor is done with tractor trolleys. Through the trolleys have been designed and put in transport, fabricated by local fabricators. No standards have been followed. The trolleys are more prone accidents due to various reasons. Most common reason in absence of any standard braking system. The design of braking system for four-wheeler Trolley have been done and presented. For synchronisation of motion between tractor engine and trolley a concept of fifth wheel coupling have been incorporated. The standard fifth wheel couplings have been designed and planned.The necessary changes will be made in hydraulic circuit of the tractor.

Key words
Tractor Trolley, Brakes, Fifthwheel coupling

1. INTRODUCTION
Farm vehicles like any other vehicle must comply with Road Traffic Regulations, a lot of which have been in Legislation since the 1960’s. The increasing number of fatalities on our roads, together with the demand for action on road safety, has resulted in stricter enforcement of these regulations. Many farmers and contractors are discovering that their trailers do not fulfill the requirements laid down in the Road Traffic Regulations. The need for such braking system is even more important with the introduction of 30 km/h tractors. The service brakes of the tractor and those of the trailer are required to be operated simultaneously by a single control (brake pedal).The service brakes on trailers are either of the hydraulic or air type. Hydraulic braking system would be adequate up to 30 km/h. Above 30 km/h the air system should be chosen. The hydraulic system is not as responsive as the air system. As the trailer speeds increase the consequences become more apparent hence the need to transfer from the hydraulic system to the air system if trailers exceed 30 km/h. The stand-activated system contains a hydraulic cylinder within the trailer stand. An efficient vehicle braking system is central to safety during transport operations, be they on or off-road, but agricultural trailer (and trailed appliance) braking systems are frequently given insufficient consideration, both at the time of purchase and during subsequent use: their initial specification and subsequent level of in-service maintenance frequently now proving to be inadequate for safe use behind modern ‘conventional’ tractors.

As safety feature in any vehicle plays the vital role in designing that vehicle. Braking system in any vehicle is thus must be designed with accuracy. The tractors used are nearly driven with speed of 30 km/h. Tractor Trolley’s used in now-a-days vehicle are without brakes. Various loads are applied on trolleys when it is loaded. During the inclinations stresses are developed on the joint between the tractor & trolley. This may cause the deformation of the joint due to stresses. In order to avoid all these problems, there is a need to apply brakes on the trolley also.

In the project an analysis of different braking systems would be done and a suitable braking system would be identified for the trolley. The most suitable braking system for the trolleys would be a hydraulic braking with the introduction of fifth wheel to connect the tractor with the trolley. The fifth wheel will assure the required constrained relative motion of the trolley with the tractor. The project work includes design of various components of the hydraulic brakes and the selection of fifth wheel coupling from the standard lot. A CAD model of the entire system will be made. The designed components will be analysed by FE method. The FE analysis of fifth wheel coupling will also be made. The implementation of the braking system will be done on the tractor and the trolley. The field trials will be done to confirm the government norms of the trolley braking system. The documentation for safety norms would be prepared for submission with the State Transport Authority.

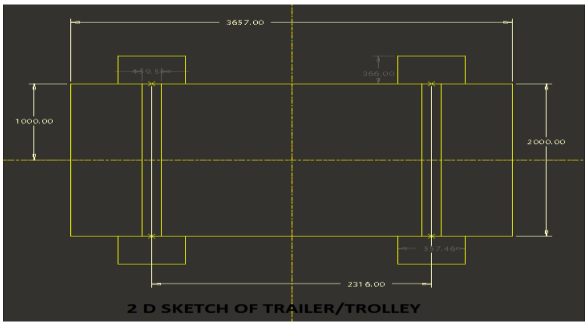
2. REQUIREMENTS OF AUTOMOBILE BRAKES
1. It should work efficiently irrespective of road condition and quality.
2. The retardation must be uniform throughout its application.
   3.The pedal effort must be within the convenient capacity of the driver.
3. It must be reliable and should not be effected by heat water and dust.
4. It should be in minimum weight.
5. It should have long life.
6. It should be easy to maintain and adjust.
7. Noise and vibrations are to be minimum.
8. There should be provision for secondary brake or parking brake.

We Use Hydraulic Braking System In Trolley:-

- The speed of tractor is generally up to 40kph. So for this speed limit use of hydraulic braking system in trolley is proper.
- The hydraulic brake system should be applied smoothly on both tractor & trolley.

- The hydraulic braking system has not been damaged in any way & the connection can be reset immediately.
- Hydraulic systems are smaller and less expensive than the air brake systems.
- Hydraulic fluid should be in-compressible. Also the hydraulic system should be air tight such that no vapor is introduced in the system.
- Hydraulic fluid must resist vaporization at high temperatures.
- The fluid that is used should be non-corrosive for the surrounding material.
- Elimination of Brake Fade.

FIG: Representation of a Hydraulic Braking System



3. DESIGN OF COMPONENTS

Analysis of forces on wheels of trolley /trailer.

R_F=(W(x+μh) cosΘ)/b

R_R=(W(b-x-μh) cosΘ)/b

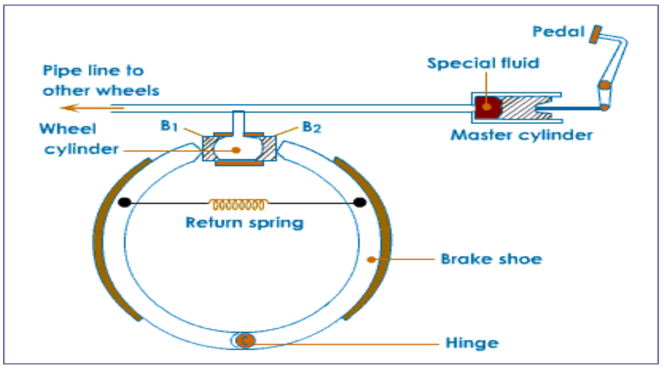
Where,

- W= weight of vehicle
- R_F & R_R = Normal Reaction at Front & Rear Wheel
- b= Wheel base
- h= height of C.G. of the vehicle from the surface of the road
- α= Retardation produced by braking
- μ= Coefficient of friction between wheels and the road surface
- X=Horizontal Distance between centre of gravity & wheel centre
- Then inertia force =(Wα/g)
- Braking force at the wheel = μR_F(at front wheel)
- =μR_R (at rear wheel)

4. DIMENSIONS OF THE TROLLEY

- W=8*10^3*9.81Kg (under full load condition)
- X=1.155 m
- μ=0.5 (in limiting case)
- h=1m
- b=2.316m
- V=35 km/hr

Considering Plane Road Condition



Θ=0, cosΘ=cos0=1

Normal Reaction at Front & Rear wheel

R_F=(W(x+μh) cosΘ)/b

R_F=(8*10^3*9.81*(1.155+0.5*1))/2.316

R_F=55815.51 N

R_F=R_R = 55815.51N

So, Braking force at front and rear wheel

R_F=R_R = μR_F =μR_R

= 0.5*55815.51 =27907.75N = 28000 N

Braking Force on One Wheel = 28000/2

= 14000 N

Distance travel before Stopping

S= V^2/2 α

We have ,

- α/g= μcosΘ-sinΘ
- α=μg (since Θ=0 for plane road)
- =0.5*9.81=4.905m/s^2

S=$(35*1000/3600)^2$/2*4.905

S =9.635 m

Torque Capacity of Wheel

τ=μF*(D/2)*(4Sinθ/2θ+Sin2θ) (D.D.B Pg 123)

=0.5*14000*(0.4/2)*(4Sin52.5/2*52.5+Sin2*52.5)

τ =41.8 N-m

Braking Efficiency

η=BRAKING FORCE / TOTAL WEIGHT

=28000/9.81*8*10^3

η =35.67 %

Stopping distance after braking

V^2-u^2=2α s where V= final velocity& u=initial velocity=0

V^2-0=2*4.905*9.635

V^2=94.519

V=9.722 m/s

Braking force on Tractor & Trolley

Kinetic energy of the vehicle

Mass m = 8 Tonne = 8000 kg and speed V=35 km/h =9.722 m/s is equal to KE

$E=mv^2/2=8000*9.722^2/2$

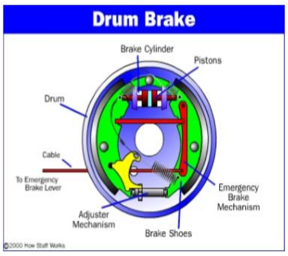
E=378069.13 joule or N-m

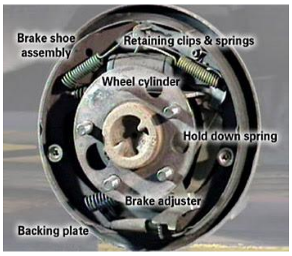
Braking distance-

Vehicle Braking distance from velocity V =35km/h is equal to s=9.635 m

For vehicle stop in desired distance we need braking force equal to: F= E/s =378069.13/9.635

F =39239.14N



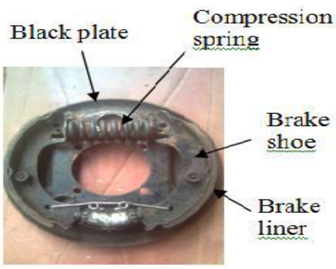


The main components of drum brakes are

1. Brake drum
2. Back plate
3. Brake shoes
4. Brake Liners
5. Retaining Springs
6. Cylinder
7. Brake Linkages

All these parts are fitted in the back plate and enclosed with brake drum.

5. DESIGN OF DRUM BRAKE



Material chosen: High carbon steel (C 95)

Shear stress=570 N/mm^2……DDB PG. NO.39

Modulus of rigidity=$7.7*10^4 N/mm^2$

Force on brake shoe F=P*A

Width of brake shoe W=80mm

Radius of brake drum r=200mm

Θ=105 degree

Area of brake shoe A=2πr*(2θ/360)*W =2π*200*(2*105/360)*80A=58643.06 mm^2

Assume safe pressure for friction lining material (steel) for brake

P=0.3 N/mm^2…..{DDB Pg-124 T XII-6}

So Force developed on brake shoe

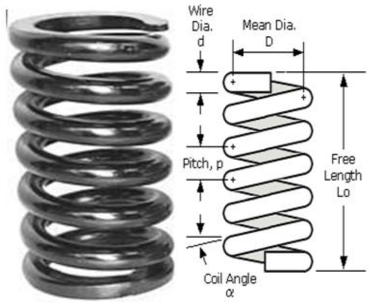
F = P*A

F = 58643*0.3

F =17593N

Torque Capacity on Brake Shoe
τ =μF*(D/2)*(4Sinθ/2θ+Sin2θ) …………DDB Pg No 123
τ =0.5*17593*(0.4/2)*(4Sin52.5/2*52.5+Sin2*52.5)
τ =52.68N-m

6. DESIGN OF COMPRESSION SPRING



Material:-High Carbon Steel (C95)

Safe pressure P=0.2 N/mm^2

Mean coil diameter Dm=36mm

Diameter of spring wire d=9mm

So, Spring index C= Dm/d =36/9 = 4

Take Modulus of rigidity G=80 GN/m^2 =$0.8*10^5 N/mm^2$

From DDB PG NO. 79, For Spring

K=Wahl's Factor

= (4C-1/4C-4)+(0.615/C)

= (4*4-1/4*4-4)+(0.615/4)

K = 1.40

Finding Static load

Ʈ= $K*(8F*Dm/\pi d^3)$…. Where Ʈ (yield strength) Ʈ=420N/mm^2……….(DDB Pg 39)

So,

F =$(420*\pi*9^3/1.4*8*36)$

Static load F =2386 N

Assume n (active coils)=8

Spring deflection $\delta = (8*F*Dm^3*n/G*d^4)$

$\delta = (8*2386*36^3*8/0.8*10^5*9^4)$

δ = 13.57mm

Stiffness q = F/ δ

q = 2386/13.57 = 175.82 N/mm

- Solid length Ls=(n+2)*d =(8+2)*9 =90mm
- Free length Lf = Ls+ δ +clash allowance

= 90+13.57+(2)

Lf =106mm

- Pitch P = (Lf-Ls/n')+d where n'=total no of coils

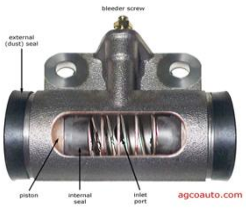
= (106-90/10)+9

P =10.6

7. Design of wheel cylinder

Cylinder diameter D=4d d=9mm Spring wire Diameter

D =4*9 =36mm



Design of link rod

Material: Steel rod SAE1030 stress=100 MPa

Load (Force developed on brake shoe) F=17593 N

C/S Area A=F/Stress

A =17593/100 =175.93 sq.mm

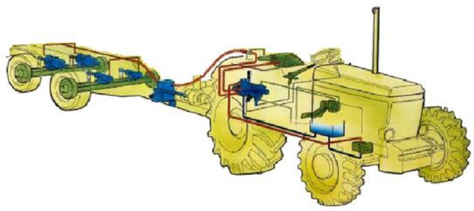
A= $(\pi/4*d^2)$ =175.93 sq.mm

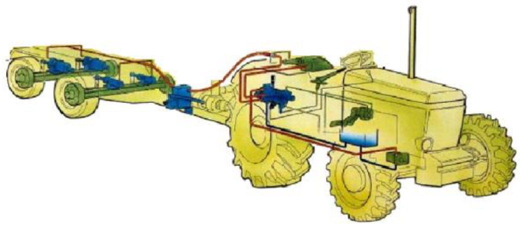
Diameter of link rod 'd' =14.96mm

Fig: Synchronization of Tractor-Trailer Braking Assembly

8. CONCLUSION

The hydraulic braking system designed for tractor trailer is similar to that used in other four wheeler vehicles like Minitrucks, Cars, Bus, etc. The standard components like Master cylinder, Tandam cyclinder , Brakes shoes, and liners have been designed and selected. The main purpose was to synchronise braking of trailer with braking of engine wheels. The synchrinisation will be possible through the use of Fifth wheel coupling. The design and selection of standard braking system components along with fifth wheel coupling is finalised





The future course of action will include

1. Fabriction of Proto Model.
2. Modification in existing hydraulic system of tractor.
3. Assembly of Fifth wheel coupling.

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