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Braking System of Light Truck

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Abstract: Steering system is to turn the vehicle and breaking system is to stop or slow the vehicle. This paper describes the various types of steering system, the hydraulic braking system and manual steering system of Light Truck. The Light Truck is four wheel drives and the hydraulic braking and manual steering are used. The braking system will include drum brake, master cylinder, wheel cylinder, brake piping and hydraulic lines. The steering system will have recirculation ball steering. In this system the function of master cylinder, wheel cylinder and drum brake are important to get actuate braking force of the drum on the wheel. In the steering recirculation ball steering, tie rod lengths and linkages are the important to be easily steered. The purpose of this thesis is how to consider and calculate the hydraulic braking system and manual steering system by using some known data and the velocity is 80 km/hr.

Keywords: steering system, breaking system, drum brake, master cylinder, wheel cylinder

1. INTRODUCTION

Nowadays, automotive vehicles are widely used in many countries for transportation and other purposes. So it is necessary to know about automotive vehicle engine in detail for mass production in our country. Automotive technology is also a required sector to develop the country rapidly. Transportation is vital to a nation's economy. Reducing the costs of transporting natural resources to production sites and moving finished goods to markets is one of the keys factors in economic competition. The transportation industry is the largest industry in the world. It includes the manufacture and distribution of vehicles, the production and distribution of fuel, and the provision of transportation services [1].

The Light Trucks are using engines to obtain driven power. They are composed of various mechanisms such as an engine, transmission system, suspension system, break system, lighting system, air conditioning and so on. Transmission system among them is essential for movement [2]. The automotive brakes system is one of the most important systems on the car. The brake system is designed to slow and stop a heavy automobile moving at high rate of speed. The brakes may be classified as the service or the primary and parking or the secondary brakes. The service brakes are the main brakes used for stopping the vehicle while in motion, whereas the parking brakes are meant to hold the vehicle on a slope. The brakes may be located either at the transmission or at the wheels [3].

Steering system is the system to turn the automobiles by using steering wheel. To turn the automobiles, toe in, toe out and chamber angle are considered to stable the automobiles. Some passenger vehicles also steer the rear wheels slightly. This gives improved maneuverability. The system is known as 4-wheel steering. It can be controlled mechanically, through a direct connection, between the front and rear steering boxes or it can be computer-controlled. With heavier vehicles, increased use of front-wheel-drive, and wider, low-profile tyres, more steering effort is needed, so power steering is used. An engine-driven hydraulic pump provides pressure that helps the driver steer the vehicle. The power steering system is designed so that the vehicle can still be controlled, even the engine or the power steering system [4].

2. DESIGN OF TWO-LINK MANIPULATOR

There are two basic types of steering boxes - those with rack-and-pinion gearing, and those with worm gearing. In both cases, the gearing in the steering box makes it easier for the driver to turn the steering wheel, and hence, the wheels. A rack-and-pinion steering system has a steering wheel, a main-shaft, universal joints, and an intermediate shaft. When the steering is turned, movement is transferred by the shafts to the pinion.

2.1 Recirculating-ball Steering

Recirculating-ball steering is used on many trucks and SUVs today. The linkage that turns the wheels is slightly different than on a rack-and-pinion system. The recirculating-ball steering gear contains a worm gear. You can image the gear in two parts. The first part is a block of metal with a threaded hole in it. This block has gear teeth cut into the outside of it, which engage a gear that moves the **pitman arm**. The steering wheel connects to a threaded rod, similar to a bolt that sticks into the hole in the block.

2.2 Rack-and-pinion Steering

Rack-and-pinion steering is quickly becoming the most common type of steering on cars, small trucks and SUVs. It is actually a pretty simple mechanism. A rack-and-pinion gear set is enclosed in a metal tube, with each end of the rack protruding from the tube. A rod, called a **tie rod**, connects to each end of the rack. The **pinion gear** is attached to the **steering shaft**. When you turn the steering wheel, the gear spins, moving the rack. The tie rod at each end of the rack connects to the **steering arm** on the **spindle**. The rack-and-pinion gear set does two things:

(1)It converts the rotational motion of the steering wheel into the linear motion needed to turn the wheels.

(2)It provides a gear reduction, making it easier to turn the wheels.

3. OVERVIEW OF BREAKING SYSTEM

The automotive brake system is a group of components designed to slow and stop each of the four wheels of the automobile. The braking action begins when the driver pushes on the brake pedal. The brake pedal is mounted on lever with a pivot near the top of the lever. The movement of the pedal causes a pushrod to move against or away from a master cylinder.

The master cylinder is mounted inside the engine compartment and on the bulkhead. The master cylinder is a hydraulic pump that is operated by the driver through the brake pedal. When the pedal is depressed, the master cylinder forces fluid under pressure through hydraulic brake lines to each of the four wheel brake units. These hydraulic lines are made of steel tubing and hoses. The lines transmit pressurized fluid from the master cylinder to each of the wheel brake units.

Disc brakes are used on the front wheels of most cars and on all four wheels on many cars. A disc rotor is attached to the wheel hub and rotates with the tire and wheel. When the driver applies the brakes, hydraulic pressure from the master cylinder is sent to the disc brake units. The pressure pushes the friction linings against the rotor to stop it. The parking brake assembly is designed to apply the brakes mechanically to prevent the car from rolling when parked or to stop the car in the event of a complete hydraulic failure.

Most parking brakes operate on the two rear brakes. Some vehicles with front-wheel drive have front-wheel parking brakes because, in an emergency stop, most of the stopping power would be required on the front of the car. The parking brake may be activated by a hand lever or a foot pedal. When the parking brake is being applied, the parking brake cable mechanically pulls on a lever that applies the brakes. Parking brakes are mechanically, not hydraulically, controlled. After calculating the required parameters of the blade, the blade 3D solid model can be created in SolidWorks and so that strength checks on blade can be made by simulating.

4. STEERING ANGLE AND WHEEL ANGLE

The ratio of steering angle is 24:1

Lock to lock is 5.1

The maximum steering angle is 360 x 5.1/2 = 918 degree.

The Maximum wheel angle is 918/24=38.27 degree

Tie Rod length =1.245 m

Calculating Toe out angle

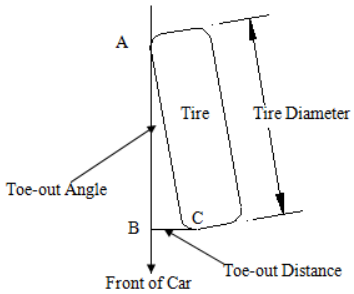

Figure 1. Toe out of tire

$$\text{Toe-out angle} = \frac{\text{Toe-out distance}}{\text{Tyre diameter}} \quad (1)$$

Table 1. Relationship of Toe-out distance and Toe-out Angle

No.	Toe-out distance	Toe-out Angle
1	10	0.921
2	15	1.382
3	20	1.843
4	25	2.306
5	30	2.765
6	35	3.226
7	40	3.681

5. ENERGY ABSORBED BY BRAKE

The energy absorbed by a brake depends upon the type of motion of the moving body. The change in kinetic energy of vehicle is

$$E_k = \frac{mv^2}{2} \quad (2)$$

Where, E_k = total kinetic energy absorbed, N-m
m = mass of vehicle, kg
v = velocity, m/s

The change in potential energy of vehicle,

$$E_p = mgs \times slope \quad (3)$$

$$E = E_k + E_p \quad (4)$$

The vehicle is to be stopped in a distance, therefore tangential braking force,

$$F_t = \frac{E}{S} \quad (5)$$

Where, S = stopping distance to stop the vehicle, m

5.1 Braking Torque

Average retarding force produced on the ground,

$$F = F_t\, r_d / r_t \quad (6)$$

The average braking torque,

$$T_b = F_t \times r_d \quad (7)$$

Where, F_t = the average braking torque to be applied to stop the vehicle, N-m
r_d = radius of cast iron brake drum, m

Volume of the drum,

$$V = \pi d_d b_d t + \frac{\pi d_d^2}{4} t \tag{8}$$

Take Cast Iron Ferrous Metals and thickness t = ¼ in
So density $\rho = 0.253\ lb/in^3 = 7003.0163\ kg/m^3$
Mass of four drums, $m = \rho\, v \times 4 = 22$ kg
Specific heat of cast iron brake drum, c = 520 J/kg °C
The energy absorbed by the brake drum,

$$H_g = m_b\, c\, \Delta t \tag{9}$$

Table 2. Results of Torque, Temperature and Resulting Force

Speed (km/hr)	Average braking torque(Nm)	Average temperature rise of the drum (°C)	Retarding force (N)
10	406.63	6.28	1228.48
20	481.67	7.44	1455.18
30	606.73	9.37	1833.02
40	781.82	12.07	2362.00
50	1006.94	15.54	3042.12
60	1282.09	19.79	3873.37
70	1607.26	24.81	4855.76
80	1982.45	30.60	5989.28
90	2407.68	37.17	7273.94

5.2 Coefficient of Friction between the Tyres and the Road

Normal force between the contact surfaces,

$$R_N = mg \tag{10}$$

The tangential braking force,

$$F_t = \mu R_N \tag{11}$$

Table 3. Results of Coefficient between tyre and road at stopping distance

Speed (km/hr)	Coefficient of Friction
10	0.21
20	0.25
30	0.32
40	0.41
50	0.53
60	0.67
70	0.84
80	1.04
90	1.26

5.3 Braking efficiency

It is the distance transverse during the time elapsed between the driver pressing the brake pedal and the being actually applied at the wheels.

$$\alpha = \frac{V^2}{2S} \tag{12}$$

$$\eta = \frac{\alpha}{g} \times 100 \tag{13}$$

Where, η = braking efficiency
α = retardation produced by braking (m/s^2)
g = gravity ($9.81 m/s^2$)

Table 4. Result of efficiency and acceleration

Speed (km/hr)	Acceleration	Efficiency
10	0.13	1.31
20	0.51	5.24
30	1.16	11.80
40	2.06	20.97
50	3.22	32.77
60	4.63	47.19
70	6.30	64.23
80	8.23	83.90
90	10.42	106.18(impossible)

5.4 Calculation of Stopping Distance

In this section, Brake applied on front wheels only, Brake applied on rear wheels only and Brake applied on all wheels are expressed as followed.

Brake Applied on Front Wheels Only

$$R_F = \frac{W\cos\theta}{(b - \mu h)} \tag{14}$$

$$R_R = \frac{W(b - \mu h - x)\cos\theta}{(b - \mu h)} \tag{15}$$

$$\frac{\alpha}{g} = \frac{-\mu x \cos\theta}{(b - \mu h)} \tag{16}$$

$\alpha = 0.394\ m/s^2$

$$S = \frac{V^2}{2\alpha} \tag{17}$$

Stopping distance, $S_1 = 24.4$ m

Brake applied on rear wheels only

$$R_R = \frac{W(b - x)\cos\theta}{(b + \mu h)} \tag{18}$$

$$R_F = \frac{W\cos\theta(x + \mu h)}{(b + \mu h)} \tag{19}$$

$$\frac{\alpha}{g} = \frac{\cos\theta(b - x)\mu}{(b + \mu h)} - \sin\theta \tag{20}$$

$\alpha = 0.407\ m/s^2$

Stopping distance, $S_2 = 23.7$ m

Brake applied on all wheels

$$R_R = \frac{W(b - x - \mu h)\cos\theta}{b} \tag{21}$$

$$R_F = \frac{W(x+\mu h)\cos\theta}{b} \quad (22)$$

$$\frac{\alpha}{g} = \mu\cos\theta - \sin\theta \quad (23)$$

$\alpha = 1.98\ m/s^2$

Stopping distance, $S_3 = 22.7$ m

$S_3 < S_2 < S_1$

Therefore, stopping distance S_3 for brake applied on all wheels is chosen.

5.5 Braking Pressure for Front and Rear Wheel

Different values of stopping distance and efficiency with speed are shown in Table 3. According to these results, the best braking efficiency can be found at velocity 80 km/hr. According to results Table 3, the best braking efficiency is 83.9% at velocity 80 km/hr.

$$E_k = \frac{mv^2}{2}$$

$$E = E_k + E_p$$

$$F_t = \frac{E}{S}$$

Total force on all wheels, F_t = 137200 N

Total force on front two wheels, F_{ftall} = 60% of F_t

For front one wheel, F_{ft} = 41159 N

Total force on rear two wheels, F_{rtall} = 40% of F_t

For rear one wheel, F_{rt} =27440N

For Front Wheel,

$$T_f = F_{ft} \times r_d \quad (24)$$

For one shoe, braking torque = 3169.3 N-m

$$\theta_1 = 25^\circ = 25 \times \frac{\pi}{180}$$

$$\theta_2 = 125^\circ = 125 \times \frac{\pi}{180}$$

Internal radius of wheel rim, r = 150 mm

Width of brake lining = 35 mm

Choose metal on cast iron as material for brake lining.

Thus, coefficient of friction = 0.4

$$T_{bf} = \mu_1 P_1 b_b r^2 (\cos\theta_1 - \cos\theta_2) \quad (25)$$

$$P_1 = 0.68\,N/mm^2$$

For Rear Wheel,

$$T_r = F_{rt} \times r_d = 4225.7\,N - m \quad (26)$$

For one shoe, braking torque = 2112.8 N-m

$$T_{br} = \mu_1 P_1 b_b r^2 (\cos\theta_1 - \cos\theta_2) \quad (27)$$

$$P_2 = 0.45\,N/mm^2$$

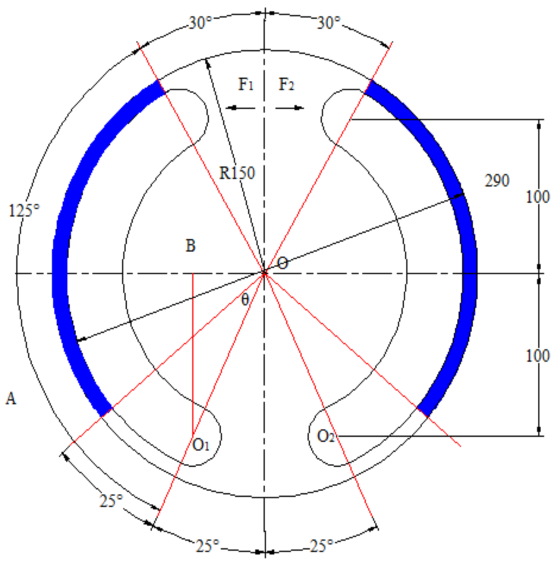

Figure 2. Standard dimension of break shoe

5.6 Force Exerted by the Wheel Cylinder at the Front and Rear Wheel

$$M_N = \frac{1}{2} P_1 b_b r OO_1 \left[(\theta_2 - \theta_1) + \frac{1}{2}(\sin 2\theta_1 - \sin 2\theta_2) \right] \quad (28)$$

$$M_F = \mu_1 P_1 b_b r \left[r(\cos\theta_1 - \cos\theta_2) + \frac{OO_1}{4}(\cos 2\theta_2 - \cos 2\theta_1) \right] \quad (29)$$

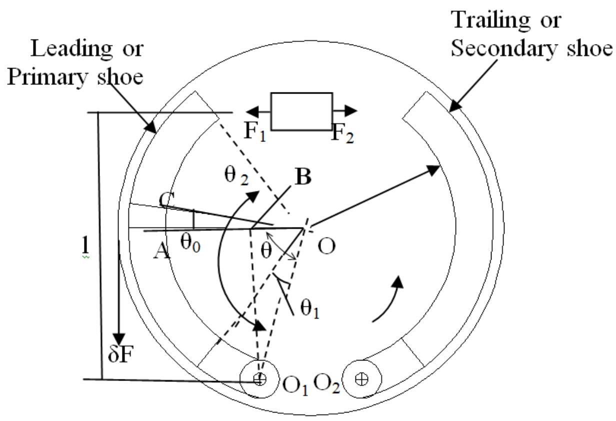

Figure 3. Forces diagram of break shoe

Force on leading shoe, $F_1 \times 1 = M_N - M_F$ (30)

Force on trailing shoe, $F_2 \times 1 = M_N + M_F$ (31)

Table 5. Result of normal force and friction force

	Normal force	Friction force
Front moment	1009	3619
Rear moment	671.55	2411.25

5.7 Master Cylinder Diameter for Front Wheel Force

By using practical experience,

r_1 = 299.72 mm

r_2 = 38.1 mm

Assume, force of foot = 40 lb = 178 N

Diameter of wheel cylinder = 1 in = 0.0254 m

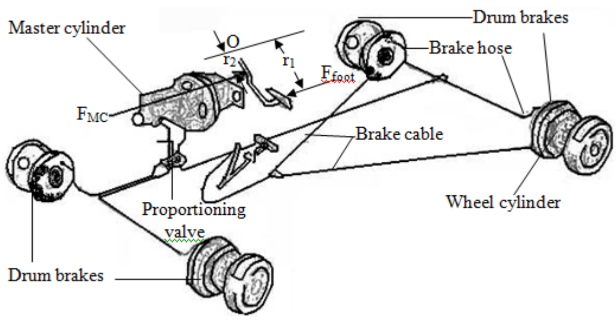

Figure 4. Layout of Hydraulic Pipe Lines

Taking moment about O,

$$\frac{\text{Force of master}}{\text{cylinder}} \times r_2 = \frac{\text{Force of}}{\text{foot}} \times r_1$$

Force on the wheel cylinder, F_w = 3619 N

Area of wheel cylinder, A = 506.7 mm^2

Pressure on the wheel cylinder, P_w = 7.14 N/mm^2

By Pascal's Law,

$$\frac{\text{Pressure on}}{\text{the wheel cylinder}} = \frac{\text{Pressure on}}{\text{the Master cylinder}}$$

$$\frac{F_W}{A_W} = \frac{F_{MC}}{A_{MC}}$$

$$A_{MC} = 196\,mm^2$$

$$d_{MC} = 15.8\,mm \approx 16\,mm$$

5.8 Master Cylinder Diameter for Rear Wheel Force

Force on the wheel cylinder, F_w = 2411.25 N

Area of wheel cylinder, A = 506.7 mm^2

Pressure on the wheel cylinder, P_w = 4.76 N/mm^2

By Pascal's Law,

$$\frac{\text{Pressure on}}{\text{the wheel cylinder}} = \frac{\text{Pressure on}}{\text{the Master cylinder}}$$

$$A_{MC} = 294.3\,mm^2$$

$$d_{MC} = 19.4\,mm \approx 20\,mm$$

Table 6. Results of energy absorbed by brake

Items	Value	Units
Volume of drum, V	0.0008	m^3
Normal force, R_N	12390	N
Brake applied on front wheel, R_F	5565	N
Brake applied on rare wheel, R_F	6597.7	N
Kinetic energy, E_k	4041600	N-m
Potential energy, E_p	123900	N-m
Total energy, E	4115900	N-m
Total force on all wheel, F_t	137200	N
Braking torque, T_{br}	4225.7	N-m

6. CONCLUSION

In In hydraulic brake system, the material of drum brake is made of gray cast iron and the master cylinder is made of cast iron. A facing of friction material called brake lining. These lining materials are generally classified as asbestos lining materials. The system is simple in construction due to the absence of brake rods, joints, etc. inherent in the mechanical. Moreover, pipelines can be bent and shaped according to the underside of the body structure. Due to absence of joints compared to mechanical brake, rate of wear is also less. The fluid exerts equal pressure everywhere in its system. For this reason equal braking effort is obtained at all the four wheels. This system is suitable only for applying brakes intermittently.

According to the design calculation, the diameter of master cylinder and wheel cylinder are increases, the pressure can be greater. When the diameter of master cylinder is too small, pressure is very low. The friction material used for disc pedal is much heard compared to that used on drum brake shoes. The reason for this is that the size of friction surface is small and very high pressures are used to push the pads into contact with the rotor. However, disc brakes are used on the front wheel, the friction power is improved.

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