Design of Pneumatic Collapsible Steering

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Abstract **– The steering wheel is the important cause of fatal injury for drivers in frontal collision. When frontal collision occurs, due to the kinetic energy of driver or occupant body, it moves forward against steering wheel and wind shield. Actually in a frontal collision forces will be first transmitted through driver's feet which act as fulcrum so the body will rotate about it. For the taller driver steering works as fulcrum. Driver head & chest hit the steering or windshield which may cause severe injury or death. Considering the injury potential of steering wheel we are presenting a new idea Pneumatic Collapsible Steering Column (PCS).**

I. INTRODUCTION

Worldwide, the vehicle accidents are increasing day by day. Frontal collision is more vulnerable than other types of collision and occurs more frequently than others. When frontal collision occurs, the vehicle hits another moving or stationary vehicle or may hit some object. As the crush proceeds into engine components, the supports of the engine are designed to minimize the risk of engine and firewall projecting into the occupant compartment.

Due to that kinetic energy driver or occupant body move forward against steering wheel and windshield. At this time vehicle is reaching maximum deceleration. Driver's and front passenger's head, neck, coxa and knees moving forward with high speed than the stationary seat under them. If the driver is fastening seat belt than their shoulder will move forward until reaches its limits which causes tissue injuries. If not than whole body will be projected on the steering or, windshield causes the death of driver. At this stage driver's head, neck, reaching at peak deceleration point. Actually in a frontal collision, forces will be first transmitted through driver's feet which act as fulcrum so the body will rotate around it. For the taller driver steering works as fulcrum. Driver head & chest hit the steering or windshield which may cause severe injury or death.

The steering wheel is the prominent cause of fatal injury for drivers in frontal collision. In cars built before 1967, the steering column was a rigid pole ending in a narrow hub. In frontal crashes, the driver would hit the rigid column, his load concentrated on the narrow hub. In crash deceleration, a large number of steering wheel designs allow high impact loads to be transmitted to the driver chest and head which may cause death.

Fig 1.1 : Fatal injury in collision [2]

In some other cases it was found that steering wheel as an active and skeletal damage to the head without deforming the wheel rim. As shown in fig 1.1, the axial movement of steering wheel is more dangerous even though forces are low. So to reduce death rate during vehicle collision, various types of collision protection devices such as Seat belts, Air bags, Collapsible steering column etc. are necessary.

II. COLLAPSIBLE STEERINGCOLUMN

When the steering column was first invented, it consisted of a single long steel rod which connecting the steering wheel to the steering gear box. While this single-piece construction was efficient, and effective in controlling the vehicle, it soon became apparent that its design was unsafe in frontal collisions. Under the single-piece system, when such an impact occurred, the steering column would often impale the driver as it was rammed toward the rear of the vehicle.

A collapsible steering column is a mechanism that is used to transfer power from the steering wheel into the steering gear box, which transfers power to turn the wheels of a vehicle. Existing collapsible steering columns still consist of a long shaft that connects the steering wheel to the steering gear box. However, the collapsible design is composed of an inner and an outer sleeve, engaged tightly together with a number of steel bearings in between the sleeves. These steel bearings are pressed into the metal sleeves, and are held in place with a strong safety resin, which is designed to harden and then shatter when a specific level of pressure is applied. A Collapsible steering part is as shown in fig 2.1

Fig. 2.1.1

Fig. 2.1.2

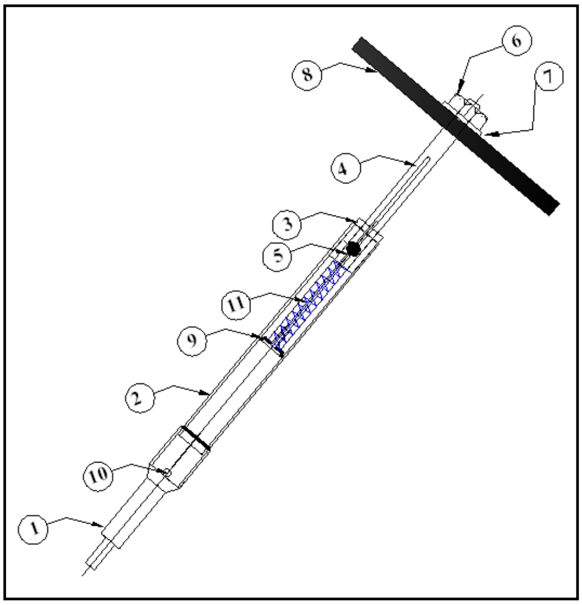
Fig. 2.1.3

Fig. 2.1.4

Fig. 2.1.5

Fig. 2.1 : Collapsible steering action

In the event of a frontal impact, the steel bearings between the sleeves break free, allowing the inner sleeve to be moved further into the outer sleeve in telescopic fashion before enough pressure is achieved to ram the whole steering column into the driver. In this manner, the energy received through a frontal impact is completely absorbed by the steering column's collapsible parts.



III. DESIGNED PARTS

The designed parts in AutoCAD 2010 for the fabrication of "*Pneumatic Collapsible Steering"* are as shown below;

3.1 Sleeve with key

Sleeve and Key arrangement is used to block the rotation of cup seal inside the pneumatic cylinder. And it transmits the input from steering wheel to the steering gear box through steering column (cylinder). Also it provides a guide way for the linear motion of collapsible steering.

3.2 *Cup Seal*

Fluid seals are available to suit single or double acting applications. They provide better sealing inside pneumatic cylinder. Cup seals are designed as a piston seal, suitable for either single acting or double acting, medium duty applications.

They are available in the following materials:

- Rubber
- Rubber/Fabric
- Polyurethane
- Leather

3.3 *Mechanical switch*

Mechanical switch is used for the opening and closing of Solenoid valve. It consists of a force receiving surface, open coiled spring of high stiffness and connection terminals. According to the applied force during collision the spring will compress and the electrical solenoid circuit will close. This switch is responsible for the release of compressed air through solenoid valve from pneumatic cylinder.

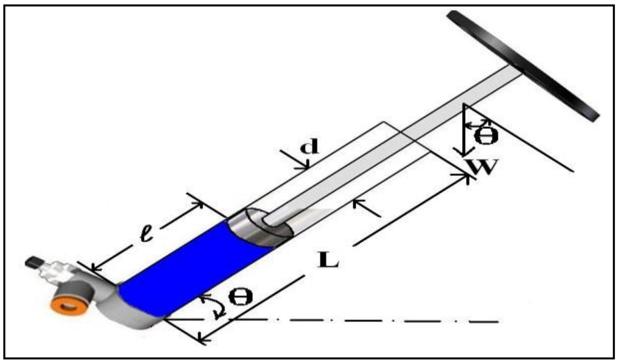
IV. DESIGN CALCULATIONS

4.1 *Pressure*

The minimum pressure required to hold the steering wheel was obtained by equating the upward forces and downward forces. The force acting upward is due to air pressure, and force acting downward is due to the weight of the steering rod and steering wheel assembly without considering the spring force.

ITEM LIST

PNEUMATIC COLLAPSIBLE STEERING COLUMN ASSEMBLY		
SI. No.	DESCRIPTION	MATERIAL
1	BOTTOM PART	M.S
2	CYLINDER	M.S
3	SLEEVE WITH KEY	M.S
4	STEERING ROD	M.S
5	BOLT	M.S
6	NUT	M.S
7	WASHER	M.S
8	STEERING	M.S
9	CUP SEAL	RUBBER
10	SOLENOID VALVE PORT	M.S
11	SPRING	M.S



Consider a Cylinder having length **L** and it includes an air column of length ℓ.

Let **W** be the weight of the upper assembly.

Equating the forces;

Upward force = downward force

Downward force $\mathbf{W = mg}\ \boldsymbol{sin}\theta$

$\therefore$ $\mathbf{W} = \boldsymbol{\rho.V.g}\ \boldsymbol{sin}\theta$

Since $\mathbf{m = \rho V}$ (4.1.1)

Where m is the mass of the steering rod

ρ Is density of aluminum bronze alloy in kg / m^3

V is volume in m^3

Upward force = pressure X area

$$\text{Pressure} = \frac{force}{area} \quad (4.1.2)$$

i.e.; from this upward pressure =

$$\frac{\rho V.g\ sin\theta}{\frac{\pi}{4}d^2} \quad (4.1.3)$$

Total volume,**V=** base area of rod x length of rod

$= \left(\frac{\pi}{4} \times (0.02^2) \times .4\right)$

$= 1.25 \times 10^{-4}\ m^3$

$\therefore$ **Mass** = **ρ.v**.

ρ= 7850 kg / m^3

$= 7850 \times 1.25 \times 10^{-4} = 0.9865$ kg

Approximated mass of steering = 2 kg

$\therefore$ Total weight =2 + 0.9865

= 2.9865 kg

$$\therefore \text{ Pressure, p} = \frac{(2.9865 \times 9.81 \times \sin 60)}{\frac{\pi}{4} \times 0.036^2}$$

$= 24{,}926.84\ {}^{N}/_{m^2} = 0.24926$ bar

4.2 Mechanical Switch

Research shows that, average duration of frontal collision is around 100 milliseconds (ms). In that time average amount of kinetic energy produced = 6733J;

For a Vehicle speed of 30mph.

i.e.: Duration of frontal collision = 100millisecond = 0.1 sec

Energy in one second, power = $\frac{\mathbf{6733}}{\mathbf{0.1}}$= 67330J/s

(4.2.1)

Vehicle speed in m/s = 30×1.606

$= \frac{48.2Km}{hr} = \frac{48.2\times5}{18}$= 13.389m/s

(1 mph = 0.44704 m / s)

We have power = Force×velocity (4.2.2)

Therefore Force = Energy/Velocity = $\frac{67330}{13.389}$ = **5032.13N**

Equating this with basic spring equation;

F = KX (4.2.3)

Where k = stiffness in N/m

Deflection X in meter

Assuming deflection as 10mm=0.01m

(Distance between the contact points in mechanical switch)

Therefore stiffness, **K=** $\frac{F}{X} = \frac{\mathbf{5032.13}}{\mathbf{.01}}$ = **5.03×** $\mathbf{10^5}$ **N/m**

This is the required stiffness of the spring in Mechanical switch.

Thus when frontal collision occurs the solenoid valve will get activated, for a force greater than 5050 N. Thus the steering will collapse.

V. FABRICATED PARTS

Cylinder (upper part)

Cylinder (bottom part)

Steering rod

Sleeve with Key

5.1 Designed parts

VI. WORKING OF PNEUMATIC COLLAPSIBLE STEERING

Working of Pneumatic Collapsible Steering (**PCS**) can be explained with the help of circuit diagram Fig. 6.1.

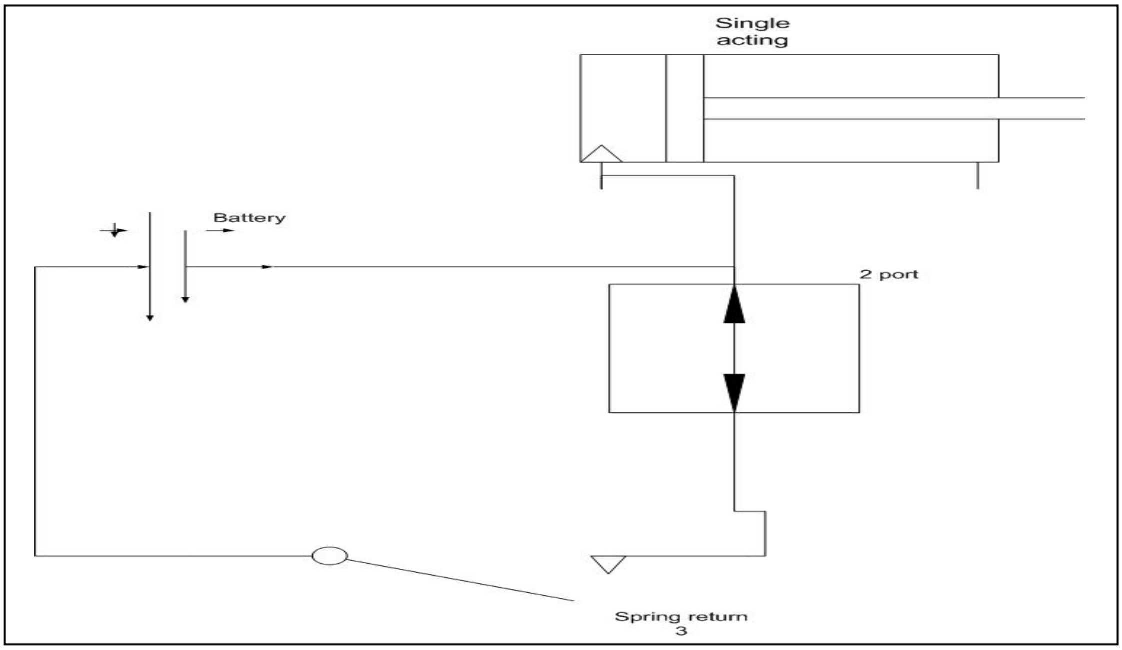


Fig. 6.1 : Working Circuit Diagram

Assume that a vehicle is fitted with PCS system. Front side of the vehicle is arranged with some mechanical switches. Thus when frontal collision occurs, one or more mechanical switch will get compressed. Thus circuit will get closed and DC current flows to the solenoid valve from battery.

Thus the compressed air from Pneumatic cylinder suddenly escapes through the solenoid valve. Thus the steering will get collapsed.

VII. THE EXPERIMENTAL SET UP OF PCS

VIII.RESULTS

Maximum height of steering = 12 cm

Response time for collapsing action of steering = between 0.1 and 0.3 seconds.

Minimum pressure required inside Pneumatic cylinder = 0.24926 bar.

Maximum pressure depends on the comfort steering height level and cup seal capacity. Finally we implemented our PNEUMATIC COLLAPSIBLE STEERING (PCS) in a Go-Kart. A go-kart is a miniature representation of a fully fledged automobile. It possesses almost all the basic maneuverability's of a regular automobile. It can used to study the basic operation and working of an automobile.

IX. CONCLUSION

As we know, the fact is very correct that accidents are increasing day by day. On considering the injury potential of steering wheel this project gives a new and more safer design for the steering wheel. We hope this project will be a helping hand to decrease the death rate due to frontal collision.

Pneumatic collapsible steering production cost is low. It can get more comfort by increasing the pressure of gas or air in it. It is sensitive since it work with sensors during collision. Steering column provides good safety device against collision. Its maintenance cost is low since need only to replace air or gas in it. The main advantages of pneumatic steering are that provides working space for proper functioning of air bag.

X. ACKNOWLEDGMENTS

I would like to express my gratitude to:

- HIRAN.K.H Project engineer @ Al Reyami group, Abu Dhabi
- TISBIN TOBY Service engineer @ POPULAR VEHICLES & SEVICES LTD

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