Design of Air Bag System by Hydraulic Circuit and Direct Acting Solenoid Flow Regulator

Challagonda Sandeep Reddy
UG Student
Department of Mechanical Engineering
Kakatiya University College of Engineering & Technology, Warangal, India

Kandagatla Uday Kiran
UG Student
Department of Mechanical Engineering
Kakatiya Institute of Technology & Science, Warangal, India

Ch. Karunakar
Assistant Professor
Department of Mechanical Engineering
Kakatiya Institute of Technology & Science, Warangal, India

Abstract

Airbags are responsible for myriad number of lifesavings as well as proved fatal and hazardous systems due to untimely, uncontrolled chemical explosion triggered by airbag control module. The victims are especially children who suffer from broken bones. The airbag chemicals include like sodium azide, potassium nitrates etc, the gases released after airbag deflation are dangerous to victims, besides these conventional method of airbag systems are highly costly that only few of the car owners can afford and other drive without them who are susceptible to fatality in case of crashes. This paper discusses the design of the airbag systems omitting the use of chemical reactions and introducing metal bumper and cylindrical pressure lines and building the hydraulic circuit, utilizing the principles of energy conversions, fluid mechanics and electronic control units associated with pressure differential sensors and solenoid actuated flow control valve which is a highly controlled method for operation of airbag which can even cutdown the overall cost to significant mark.

Keywords: Air Bag Control Module, Chemical Explosion, Fluid Mechanics, Hazardous Systems, Hydraulic Circuit, Sodium Azide

I. INTRODUCTION

Vehicle collisions are inevitable on the highways and on other routes, mainly head on collisions are proved to be fatal on highways where the speed of the vehicles is usually high.in 2013 itself there are 1.25 million accident deaths globally Accidents are caused by numerous reasons and automotive manufacturers mainly concern for the passenger safety during the design of a vehicle and made many developments in both vehicle safety and passenger safety. Air bag is one of the restraint safety method introduced in 1973 ever since the passenger safety was increased and reduced fatalities. The cushioning effect of the airbag saves the passenger from hitting to the steering wheel and dash board during collisions. Air bags are generally high in price and shows a significant figure in amount to install them in a car, once the airbag satisfies the purpose it is non- usable and the entire system must be replaced and again airbags have to be reinstalled freshly, which would not be economical since they are in exorbitant in price and installing. Unlike vehicles manufactured in United States and European Union some vehicles in India on road are without airbags in them. In this case passengers are susceptible to fatalities if the crash occurs, hence the airbag system must be designed with optimal cost and robust in nature, reusable without discarding them. In this paper the design of airbag system using the impact energy generated during the vehicle collisions is tuned into increase in the pressure of newly introduced pressure lines beneath the chassis of the vehicle integrated with the entire system the thick cylindrical pressure lines are extended to the proximity of the steering wheel where the pressure line is connected to a small cylindrical chamber initially filled with compressed air. The working fluid inside the pressure lines is water which is incompressible and an exemplar to transfer the pressure energy to the compressed air chamber the air chamber contains, differential pressure sensor and direct acting solenoid flow valve mounted on it. This valve is guided and monitored by the electronic control unit

When the collision takes place the thermoplastic bumper beam transfers energy to a metal bumper which the next to it, due to the impact force the bumper pushes the pistons inside the cylindrical tank filled with water and whose openings are into the cylindrical pressure lines containing water and the end of these lines are in to the compressed air chamber. When the pistons are displaced by impact force the pressure is developed and transferred through the pipe lines. This developed pressure is transferred undiminished throughout the hydraulic circuit and also to the compressed air chamber containing differential pressure sensor such pressure reaching upon the air chamber an movable disk which separate both media acting as piston displaces and still increase the pressure inside the compressed air chamber such increase is perceived by sensor placed in the chamber this difference in pressures is sent as input signal to the control unit which responds by giving output signal to the solenoid actuated valve which opens in 5-

10 ms and the compressed air which is further compressed by hydraulic pressure rushes in to the nylon airbag in steering wheel and cushioning effect is produced and acts to mitigate the effects of impact on passenger.

II. CONTEMPORARY AIRBAG SYSTEM

Most modern cars use a airbag system which receives input signals from crash sensors and safety sensors the airbag control module receives and calculate the angle of impact and sends the appropriate signal to the concern airbag where the explosive chemical receives 5-12 voltage and at 300oc the chemical explodes releasing the nitrogen gas at very rapid rate, this explosion happens inside the wheel and airbag rushes out bursting the plastic cap on steering wheel. these chemicals are highly toxic and hazardous too this model can be tricked easily by sensors pseudo reception like displacing them and decelerating them such events occurs out of time, opening of airbags in such inappropriate times can victimize somebody from an infant to an adult resulting in bone breaking to sometime death and expensive loss is grieved since airbags cannot be reused.

III. DESIGN CALCULATIONS

A. Thickness of the Pressure Lines and Force Acting on Vehicle:

Mass of the car = 1500kg;
Speed during impact = 30 km/hr
Velocity = 8.34m/s
Let the car has been decelerated in 50ms
The force acting on the car is taken as F_i = (mass of car) *(deceleration of car from 30 to 0 in 50ms)
$F_i = 1500*(8.34/50) *10^3$ N
$F_i =$ 250 KN of force on vehicle
The bumper receives this force and transmits to metallic bumper and applies pressure on pistons in cylindrical tank each bumper receives 50 KN of force on it
5 pistons connecting tank and piston with radius 2cm
Pressure(P) on five pistons = Force/ area= $5(50/12.56) *10^7$ N/m^2
Pressure in tank = pressure applied by all the pistons = $19.90*10^7$ N/m^2 = 200 Mpa of pressure in tanks and in cylindrical pressure lines
Pressure inside thick cylinders and designing =
Minimum pressure at 30 kmph collisions is found as 200 Mpa and taking the maximum pressure is 8 times the minimum pressure which is proportional to vehicles speed
The axial stress is given as $\sigma_a = (p_i r_i^2 - p_o r_o^2)/(r_o^2 - r_i^2)$
The hoops stress is given as $\sigma_c = [(p_i r_i^2 - p_o r_o^2) / (r_o^2 - r_i^2)] - [r_i^2 r_o^2 (p_o - p_i) / (r2 (r_o^2 - r_i^2))]$
The radial stress inside tube is as same as pressure inside it $P_r = \sigma_r$, r = inner radius in this case since maximum pressure is developed only inside of cylinder

Table - 1.1
Pressure line specifications

S.no	*Specifications*	*value*
1	*Permissible hoop stress(σ_c)*	*1800 N/mm^2*
2	*Inner radius of tube(r_i)*	*40 mm*
3	*Outlet radius of tube(r_o)*	*45 mm*
4	*Pressure on outer tube(p_o)*	*nil*
5	*Total Pistons in tank*	*5*
6	*Area of piston*	*1256 mm^2*
7	*minimum vehicle speed*	*30kmph*
8	*Maximum pressure @240kmph*	*1600 Mpa*
m	*Inside pressure (p_i)*	*200Mpa*

The maximum pressure for failure in pressure line circuit is hoops stress obtained by σ_c is 1800Mpa or 1.8 Gpa

This type of steel is employed in the Mazda passenger car CX-5 as rear and front ideal beams would be an ideal material for pressure tube lines. to the compressed air chamber and mounted with direct acting solenoid valve which operates in milliseconds as response time and operate very quickly, thus the pressurized air fills the bags and deflates with passenger impact with the airbag. In this model the airbag opens only when pressure detection of a pre-set value is crossed and carefully monitored by control unit. This model completely omits use of chemical in the airbag inflation and untimely opening is thereby eliminated

This model can be multiple times used unless the cylinder lines are completely damaged and flow valve is again brought into position and compressed air is readily available and very cheap in price unlike chemicals which produce choking gases after deflation.

B. Modelling of the System:

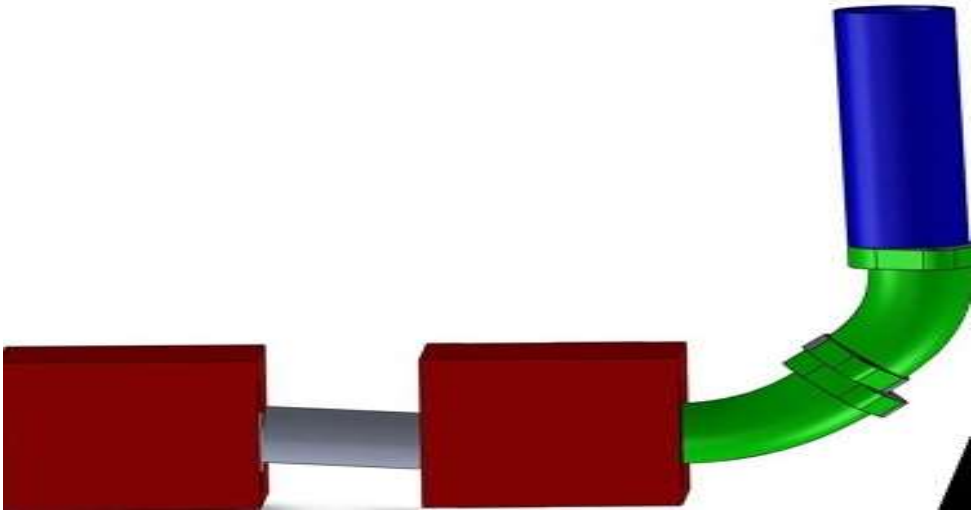

Fig. 1: Modelling of the System

The thermoplastic bumper is placed next to first maroon bumper when the vehicle takes impact it transfers the impact through pistons connecting metal bumper and cylindrical tank second from left, where the pressure rate is very high. The pressure lines in green are connected from tank into compressed air chamber in blue fitted with direct acting solenoid valve

C. Process Diagram:

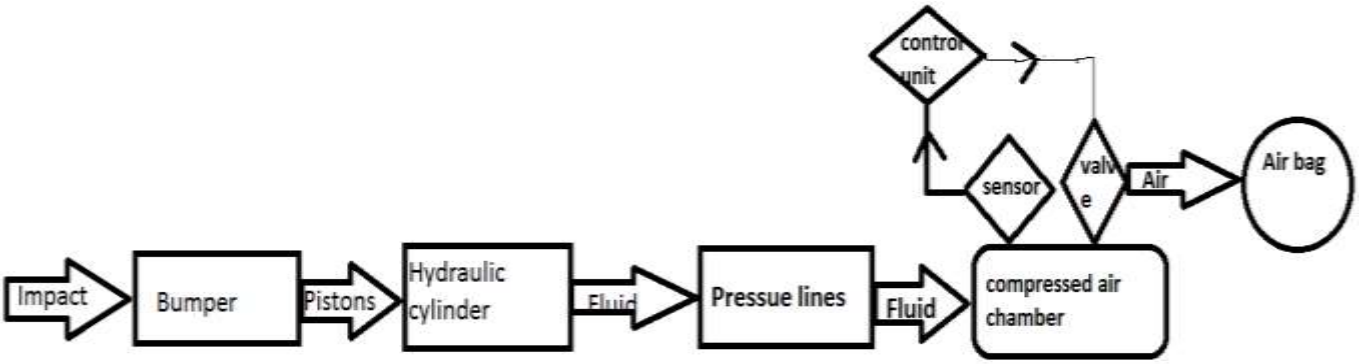

Fig. 2: Process Diagram

D. Objective Considerations:

This model is purely applicable to commercial passenger vehicles ranging from 30kmph to 250kmph speed.
The opening of valve is done due to pressure difference which is initially a pre-set value given to the control unit.
This type of design is only done for driver side airbag.

IV. RESULTS

The activation of airbag lies in several factors like minimum velocity during impact, deceleration during the crash and Crash sensors readings, here the airbag is designed to open at 30kmph impact relative to a stationary barrier and the load acting on the bumper of car 250KN caused in impact lasting 0.05 s. The rise of pressure inside air chamber can also be taken as cut off for deployment of airbag.

V. FUTURE SCOPE

Vehicle collisions occur in many ways raging from head on to roll over where this paper discussed only for head on type and further advances can be made for side airbags as well as during rollover side. There are ample of applications of these air bags like space applications during landing and diving down. Due to the flow valve controlled flow of air is achieved by also introducing a PID controller valve can be opened fully or partially which also reduces the Force with which it opens. Parameters like angle of collision and responding to it can also be integrated to this system as future scope.

REFERENCES

[1] http://www.nhtsa.dot.gov/cars/testing/procedures/TP- 581-01.pdf.
[2] Alen John, Nidhi, "Modelling and Analysing of Automotive Bumper, "International Journal of Engineering Trends and Technology, vol-15, No-7, Sept 2014
[3] Barlow, P. 'Force exerted by hydraulic pressure in a Bramah press', Trans. Instn civ. Engr's 1836 1, 133.
[4] Maccary, R. R., Fey, R. F. 'Design of thick-walled pressure vessel shells', Chem. Engr 1949 (Sept.), 105
[5] A review of airbag test and analysis M. U. Khan & M. Moatamedi International Journal of Crashworthiness Volume 13, 2008
[6] A. Ulas, G.A. Risha, K.K. Kuo," Ballistic properties and burning behaviour of an ammonium perchlorate/guanidine nitrate/sodium nitrate airbag solid propellant
[7] ankit v gujrathi, Dr. Dhananjay r. dolas an overview of automobile airbag defects; International journal of engineering sciences and research technology
[8] Response times' asco-solenoid -valve information'-engineering information
[9] A.K. roy and s.w tsai- design of thick composite cylinder vessels-journal of pressure vessel technology-volume 110, issue 3
[10] Rakesh Reghunath, Sammon Korah- Analysis of thick walled internally pressurised cylinders, Journal of Basic and Applied Engineering Research-volume 1
[11] Qayssar Sayeed masikh, Dr. Mohammed tariq, Er. Prabhat Kumar Sinha- Analysis of thick and thin pressure vessels for different materials-International journal of mechanical engineering and technology- volume5, issue 10