RESEARCH ARTICLE OPEN ACCESS

Designing Of Hydraulic Bollard System Using Accumulator Bladder for Better Security Solutions

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ABSTRACT
Bollards are largely used for stopping/control of vehicular traffic and allow the pedestrians passage at entry and exit points for better safety and movement control indifferent places like Shopping malls, Govt. Building, DRDO's, Military Installation , Airport, Oil Refineries and Depots, Gas Plants, Educational Institutions etc. Bollards can be operated manually, electrically, or hydraulically and respond to a wide range of security specifications and design requirements. A bollard designed with hydraulic accumulators system proves to be more successful in providing protection to pedestrians and infrastructure. A hydraulic accumulator stores fluid under pressure and can serve a number of functions within a hydraulic system. It's an item that can provide year of trouble-free service. Thus in country like India, where population rises with very high rate and no control on traffic Bollards are one of the only choices for pedestrian friendly protection from vehicle attack.

I. INTRODUCTION

Suitable for both high-security and traffic control, Bollards have been proven to be durable, reliable and a perfect solution for heavy duty application. The threat of traffic and dangerous road conditions are a daily reality for pedestrians and one of the reasons why many People choose to drive for short distance trips that could easily be made on foot (22% of citywide driving trips are 1 mile or less in length). Elsewhere in the city, bollards manage and direct traffic flow, separate bike lanes from traffic, mark off taxi queuing areas, protect pedestrian space, draw driver's attention to traffic calming measures, prevent vehicles from parking on sidewalks, test roadway redesign and sidewalk widening and guard against potential terrorist threats. They act as barrier to control vehicles and used for security, safety and social reasons. Bollards can be carried out manually, electrically, pneumatically or hydraulically and respond to various security specifications and design requirements [1]. Bollards are manufactured from a diverse range of materials, each providing a range of different characteristics and functionality. Security bollards are normally manufactured from stainless steel or steel, aluminum, timber and with a limited selection manufactured in pre-cast concrete [2]. There are many different types of traffic posts like locking & removable, fixed type, retractable and non -retractable which serve different purposes depending on where they're located. Many cities are taking more safety precautions that are more visually appealing and attempting to ease the flow of traffic, all while protecting pedestrians more and more. Nowadays Hydraulic rising bollards are designed especially for high security vehicle entrances and for locations that has to be closed for motorized traffic on specific times (like private roads, controlled parking areas, industrial areas, shopping lanes, marketplaces etc). . Bollards are driven hydraulically and the hydraulic drive unit is placed in an installation cabinet close to the bollards.

II. METHODOLOGY

Manufacturing of bollard system is done by using different performance categories, testing methods, design calculations and guidelines [3].

Design Calculation:

Electro-Hydraulic Bollard consists of 3 cylinders of same sizes viz. Bore Diameter (**D**): 32mm, Piston Rod diameter (**d**): 25 mm, Stroke Length from BDC to TDC (**S**): 760 mm. Stroke Timing (**ST**) from BDC to TDC & vice-versa: 5 seconds. Total Force/Weight on 3 cylinders **(F)**: 2.5 tons.
Cylinder calculations are as follows:
Area of Bore Side of each Cylinder: $A = \pi D^2/4$.

AB = 0.785*3.2*3.2 cm2

$\boldsymbol{A_B = 8.04}$ **cm^2**

- $\boldsymbol{A_{BT}} = 3 * \boldsymbol{A_B}$
- $A_{BT} = 3 * 8.04 \text{ cm}^2$
- $A_{BT} = 24.12 \text{ cm}^2$

Area of Annulus Side of each Cylinder: $A = \pi(D^2 - d^2)/4$.

$A_A = 0.785 * (3.2 * 3.2 - 2.5 * 2.5) \text{ cm}^2$

AA= 3.13 cm2

- AAT = 3* AA
- AAT = 3*3.13 cm2
- AAT = 9.39 cm2

Volume required for each Cylinder: V =Area * Stroke Length.

Volume required on Bore Side of each cylinder:

VB=AB *S.

- 8.04 * 76 cm3
- 611.04 cm3 (Now 1 cm3 = .001 ltrs)
- 0.61 ltrs

For 3 nos. of Cylinders: VBT : VB *3 liters

VBT : 0.61*3 liters

VBT : 1.83 liters

Volume required on Bore Side of each cylinder:

AA*S.

- 3.13 * 76 cm3
- 237.88 cm3 (Now 1 cm3 = .001 liters)
- 0.238 liters

For 3 nos. of Cylinders: VAT : VA*3 liters

VAT : 0.238*3 liters

VAT : 0.71 liters

The three Cylinders have to operate within 5 seconds to lift the Bollard & to perform required safety operations. For this we need to provide the fluid to the Bore side of the Cylinder at a particular flow rate that could meet the function.

Similarly fluid needs to be admitted to Annulus side of the cylinder to retract the cylinder down. For this we will be requiring a Hydraulic oil Pump with a specific flow rate that could lift the cylinder up-to its full stroke length within the specified timing. Flow rate required to Lift/Retract the cylinders to full stroke length: (Volume/Stroke timing) liters per minute.

Flow Rate required to Lift the cylinders: QBT : VBT / ST

(1.83 *60) /5 liters per minute

22 liters per minute.

- Flow Rate required to retract the cylinders: QAT: VAT / ST
- (0.71 *60) /5 liters per minute 9 liters per minute

Since the maximum Flow rate required is during Lifting hence the pump flow is selected according to the Lifting operation requirements. Also since it is a mechanical system there will be losses like slippage, leakages etc. which needed to be compensated & therefore a margin over the required flow rate is required.

We have considered 20% margin over the required flow rate i.e.: Required flow rate * 1.20

- 22*1.20 liters per minute
- 26.4 liters per minute
- Approx. 27 liters per minute.

The Pressure required to Lift the cylinders against the load is calculated using Pascal's Law which states that:

Pressure = (Force or Weight/Area) Kg/cm2 or bar

Hence, Pressure Require for Lifting the Cylinders:

PBT = Force/ ABT

- $\boldsymbol{P_{BT}}$ = 2500/24.12 Kg/Cm^2

PBT = 103.6 Kg/Cm2

Due to mechanical System there will be some losses such as heat, pressure drop across valves & in Pipes/Tubes; we have taken 10% margin over the required pressure for lifting.

Therefore the Design pressure is taken as: PD - PBT * 1.1

- PD = 103.6*1.1 Kg/Cm2
- PD = 115 Kg/Cm2

The Hydraulic Oil Pump can be of different types such as External Gear Pump, Vane Pump, variable displacement axial piston Pump, and Internal gear Pump etc. Any of these pumps can be used depending on the application of the system.

Now for driving the Hydraulic oil pump we need an AC Electric Motor of a particular rating. The Motor rating depends upon three factors viz. Pressure, Flow & efficiency of the Pump.

Motor kW can be calculated by below given formula:

1. Motor Rating (kW):- (Pressure X Flow rate)/(600 X Overall efficiency of Oil Pump)

Efficiency of Oil Pump varies from type to type:

1. Variable Displacement Axial piston pump : 90%
2. External Gear Pump : 65%
3. Internal Gear Pump : 75%
4. Vane Pump : 80%

Reservoir Calculation:

Hydraulic Oil Reservoir generally is of Rectangular design. They are used to store the fluid when the system is idle or in running condition. Design of Oil Reservoir should be such that it can dissipate as much as heat from the hydraulic oil in reservoir & there should be enough retention time for dirt & slug to settle down at the bottom. Oil reservoir should consist of a Baffle plate which divides the reservoir in Dirty/Return Compartment & Clean/Suction Compartment. As a standard practice Baffle plate at installed at 2/3rd distance from Dirty/Return Compartment. Reservoir should have at least 2 manhole covers so that cleaning & maintenance could be down during shut down off system. Oil reservoir capacity depends upon the total oil volume present in the system i.e. in pipelines, Hydraulic cylinders, valves etc. As a standard Oil reservoir effective capacity i.e. Oil Volume is taken as 5 to 6 times of working pumps flow rates. Gross capacity of Oil reservoir is taken as 20% extra over effective volume so as to keep space for air degassing & breathing.

Hence in our system Effective Oil reservoir capacity is: Oil Flow Rate * 5 liters

QBT * 5 liters

- 22*5 liters
- 110 liters

And therefore Gross Oil reservoir capacity is: Effective capacity * 1.2 liters

- 110*1.2 liters

- 132 liters

Hence Oil Reservoir of 132 liters of capacity will serve the purpose for us.

III. Accumulator

Hydraulic System consist of various components that power by Electrical supply. If the Supply fails the system shuts down or if failure of any components occurs such as pump, motor etc. end function may not be achieved as desired.

To remove this malfunctioning hydraulic system is equipped with an Accumulator or a bank of accumulator. An Accumulator is a device which stores fluid under pressure as hydraulic energy & delivers whenever there is a demand in the system. It is analogy to Flywheel in a mechanical system. Accumulator generally has partition in which one side is filled with Nitrogen/Inert gas (Oxygen should not be used) the other side of the partition is filled with hydraulic fluid.
Accumulators are of three types which are as follows:

1. Bladder Accumulator : The partition element is Bladder
2. Piston Accumulator: The partition element is Piston
3. Diaphragm Accumulator: The partition element is Diaphragm.

For calculation of accumulator we require four parameters which are:-

1. Maximum Pressure: P2-Maximum System Operating Pressure
2. Minimum Pressure: P1-Minimum system operating Pressure
3. Pre-charge pressure: P0-Pressure at which the nitrogen gas to be filled inside the accumulator (Generally taken as 90% of the minimum operating pressure)
4. Differential Volume: ΔV-The Volume which accumulator needs to store so as to deliver during emergency situation.

Other parameters are: - V0: Total Gas Volume.
V1: Volume at Minimum pressure.
V2: Volume at Maximum Pressure.

In our System the above parameters are as follows:-

1. P2:- 110 bar.
2. P1:- 70 bar.
3. P0:- 63 bar.
4. ΔV: - 3 liters.

IV. RESULTS

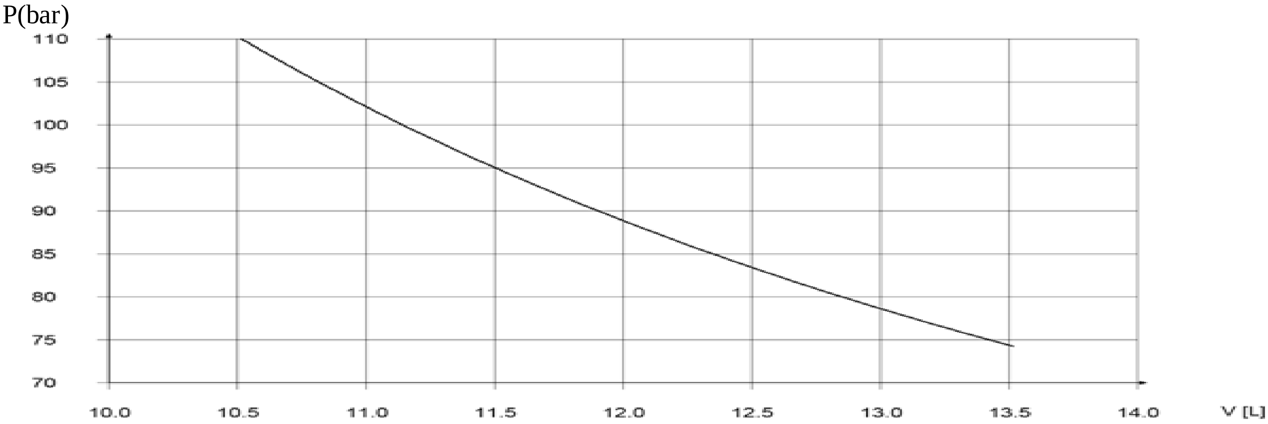
Hydraulic accumulators store hydraulic fluid under pressure. Pressure is supplied through a bag,diaphragm or piston by either a spring, or pressured gas (most common). Accumulators are inherentlydynamic devices – they function when configuration changes (actuators moving, valves opening, etc.) areoccurring within a hydraulic system. Accumulators respond very fast to configuration changes, nearlyinstanteously for gas accumulators. The capability and affect of the accumulator is determined by theoverall volume of the accumulator and preload/precharge of the spring/gas.

Result: - A numerical simulation is performed using the explicit dynamics module from Ansys

Pre-selection & Result at working Temperature 15^{0}C:

Pressure data [bar]	Temperature data [°C]	Volume data [L]
Max. working pressure : 110	Min. temperature : 15	Differential Volume : 3
Min. working pressure : 73.08	Max. temperature : 45	Accumulator Gas Volume : 18.4
Pre-charge pressure : 63	Pre-charge temperature : 20	
Gas Pressure : 61.75		
Discharge-adiabatic (fast)		
Gas Type : N2		
Charge-isotherm		

Cycle	t [s] (tot.)	t [s] (cyc.)	p [bar]	T [°C]	V [L]	Delta V [L]	Q [L/min]
1	0.000	0.000	110.00	17	10.516	0.000	0.600
1	1.000	1.000	100.38	7	11.116	0.600	0.600
1	2.000	2.000	92.26	1	11.716	1.200	0.600
1	3.000	3.000	85.34	-5	12.316	1.800	0.600
1	4.000	4.000	79.39	-10	12.916	2.400	0.600
1	5.000	5.000	74.22	-14	13.516	3.000	0.600



Simulation: PV cycle

V. CONCLUSION

Bollards are designed to offer an impact-resistant barrier to vehicle access, whilst allowing access to pedestrians. Such installations may range from shopping centre and complexes, stadiums, sportcentres, promenades, airports and ports. Bladder accumulators provide a means of regulating the performance of a hydraulic system. They are suitable for storing energy under pressure, absorbing hydraulic shocks, and dampening pump pulsation and flow fluctuations. Bladder accumulators provide excellent gas and fluid separation ensuring dependable performance, maximum efficiency, and long service life.

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