International Journal of Advance Industrial Engineering
E-ISSN 2320 –5539

Available at http://inpressco.com/category/ijaie/

Research Article

Design and Development of Universal Test Bench for Testing Valves of Automobile Braking System

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Received 01 July, Accepted 02 Sept 2017, Available online 14 Sept 2017, **Vol.5, No.3 (Sept 2017)**

Abstract

University Test Bench has been successfully designed and developed for testing valves of brake system. The test bench frame was fabricated from two hollow aluminum sections of 40mm X 80mm and 40mm X 40 mm respectively. The overall dimension is 1850mm × 1750mm × 660mm, the bench include panel of size 850mm × 1850mm × 300mm size to accommodate tubes, pressure gauges, ball valves, FR uni, and quick coupling connectors, down compartment 630mm × 850mm × 1850mm size to accommodate 40 L, 5 L and 0.75 L air reservoir tank.

Keywords: *Brake system, test bench, relay valve and pressure proportional valve.*

1. Introduction

The safe operation of any vehicle on the road depends, on a properly operating brake system. Most commercial vehicles such as trucks, tractor–trailers, buses, etc., are equipped with an air brake system. Any defect in a brake system can degrade its performance seriously and can lead to accidents.

The braking system have many types of pneumatic valves as foot and hand brake valve, load sensing valve, relay and pressure proportional valve. As performance testing of valves is difficult on manufacturing line. Therefore Universal Test Bench is developed for QA/QC department for testing performance of valves.

The Test Bench is fabricated from aluminum section, consists of six outputs and four inputs ports, coupled with an individual pressure gauge. Out of four inputs two inputs are directly connected and remaining two are connected through fine setting valve to 40L tank. Out of six outputs four outputs are connected to 0.75L tank and two outputs are connected to 0.75L and 5L tank through three-way ball valve.

The organization of the paper is as follows. Section 2 is review of literature. Section 3 briefly explains layout of test bench. In section 4, various components used in test bench are discussed. Section 5 describes notations on test bench. Section 6 gives details about checking of leakages in pipe connections. In section 7 test on relay valve and pressure proportional valve is explained. Section 8 discusses the result of test carried out in section 7. Section 9 concludes the paper.

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2. Literature Review

M. Carello, A. Ivanov and L. Mazza have given test methodology to determine the flow parameters, such as pressure drop and flow-rate, for straight pipes. The experimental tests were carried out using a properly instrumented test bench and the curves pressure drop vs. flow-rate, varying the upstream pressure, was obtained. The tests were made on pipes with different internal diameters, corresponding to common industrial size.

The system designed by Mujie You, Junzhizhang, Dongsheng sun, Jinfung Gou., to control and diagnose air brake systems in order to both sustain and improve their performance. A system developed is a hybrid model for predicting the response of the relay valve used in air brake systems of commercial vehicles.

The practical situation of high pressure pneumatic control valve performance test process is discussed by Xudongpana, Guanglinwang, Guoyu Shen, RuiqiSong[3], automatically testing has been achieved through the development of dedicated test software. The precision and operational performance of this system is verified through experiment.

S.V. Natarajan, S.C. Subramanian1, S. Darbha, K.R. Rajagopal discussed the feasibility of pneumatic proportional valve as pressure regulator element .A nonlinear mathematical model was build and verified through experiment, the effect of main physical and geometrical parameters on characteristic of valve were analyzed based on model and suggestion of valve design are given.

In this paper design and development of Universal Test Bench for testing automobile valves of braking system is explained.

3. Layout of Frame

The Universal Test Bench is fabricated from two hollow aluminum sections of 40mm X 80mm and 40mm X 40 mm as aluminum has less density compared to MS and SS so aluminum (HE-30) section is selected for structure of Test Bench. Figure 1 shows Frame of Universal Test Bench.

Figure 1 Frame of Universal Test Bench

The overall dimension is 1850mm × 1750mm × 650mm, height of bench is 1750mm equal to the nominal height of operator so it is easy to read reading of pressure gauges. Aluminum Panel of 850mm × 1850mm × 10mm size is used to accommodate tubes, pressure gauges, ball valves, FRL, and quick coupling connectors. Five pressure gauges are at 1630 mm and five are 1430mm from ground for measuring accurate reading. Figure 2 shows layout for pressure gauge on Universal Test Bench.

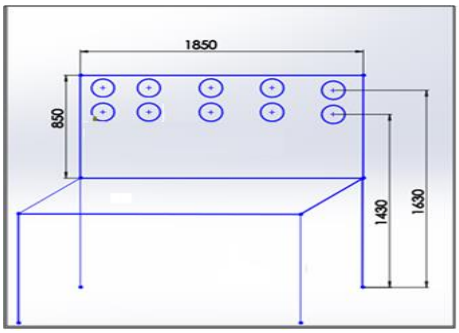

Figure 2 Layout of the holes for pressure gauges on Universal Test Bench

The base length of valves is 300 × 300 mm and two fine setting valves are to be accommodated on working platform, while minimum three valves at a time can tested on platform, therefore total 650mm × 1850 mm lengths provided for frame, height of platform is kept at 900 mm from ground level so testing component can be easily placed of work platform Figure 3 marked portion show working platform of Universal Test Bench.

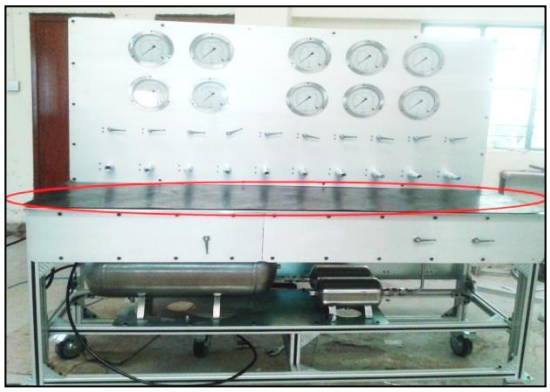

Figure 3 Working Platform of Test Bench

The platform has two layers 6mm thick SS plate for strength and 3mm rubber mat for easy placing object, height of platform is kept at 900mm from ground level for aesthetics and ergonomics consideration. Figure 4 show CAD image of Universal Test Bench.

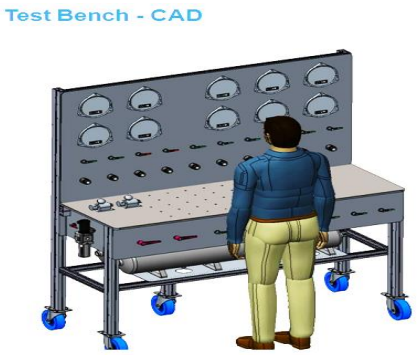

Figure 4 Universal Test Bench CAD Drawing

4. Components

(i) Quick Coupling Connector**:** For easily connect or disconnect of port self-closing quick coupling connector is used. It has two parts male part is quick coupling plug and female part is quick coupling socket. Plug and socket are selected from Festo catalog . Figure 5 shows quick coupling connector.

Figure 5 Quick coupling connector

(ii) Reservoir: The maximum and minimum tank capacity for valve checking requirement is 4.5L and 0.6L and operating pressure is maximum 16 bars. The tanks are selected from Festo catalog . In Festo catalog tank of 0.1L, 0.4L and 0.75L are available out of which 0.75L tank is selected for maximum storage while in tank 5L, 10L, 20L and 40L were available, as valves to be checked maximum tank capacity need is 4.5L so 5L

tank is selected. For collecting compressed air 40L tank is selected so maximum air can be stored for testing valves. Table 1 shows basic features of tank selected form Festo catalog 0.75 L tank is mounting is done by retaining clips, while 5.0L and 40L tank are connected through holes, Figure 6 shows 0.75L tank and Figure 7 shows 5L and 40L tank image.

Figure 6 Tank 0.75 L

Figure 7 Tank 5L and 40 L

Table 1 Technical data of reservoir

Tank capacity	0.75 L	5.0L	40.0L
Pneumatic connections	G 1/4	G 1	G 1
Type of mounting	Retaining clips	Via through hole	Via through holes
Installation position	Any	Condensate drain download	Condensate drain download
Weight (g)	736	3581	20416

(iii) Fine Setting Valve

The pressure in 40L Tank is equal to pressure set on FR unit which is maximum 12.5 Bar, but some brake valves max operating pressure is lower than 10 bar so two input ports of test bench are connected through fine setting valve which control the pressure form 0 to 10 bar. Figure 8 shows image of fine setting valve

Figure 8 Fine Setting valve

5. Notation on Test Bench

There are four inputs out of which two inputs are variable pressure line and two are fixed pressure line and six outputs out of which four outputs are connected to 0.75L tank and remaining two are connected to 0.75L and 5.0 L tank through three way ball valve. Figure 9 shows the notation of ports on Universal Test Bench.

Figure 9 Notations of port on Universal Test Bench

Table 2 Input Lines on Universal Test Bench

Line	Port Number	Valve	Notation
Input Port	41 and 42	3-Way Ball Valve	Exhaust Port
			Exhaust Circuit
			From FSV to Port
	11 and 12	2-Way Ball Valve	ON
			OFF

Table 3 Output Lines on Universal Test Bench

Line	Port	Valve	Notation	Tank
Output Port	21	3-Way Ball Valve	1. Exhaust Tank 2. Exhaust Tank and line 3. To Tank	0.75 L
	22			
	23			
	24			
	25			0.75 L and 5L
	26			

Table 2 show notation on the bench *port 41 and 42* are connected through FSR (fine setting valve*), port 11 and 12* are connected to 40 L tank, output *port 21, 22, 23 and 24* are connected to 0.75 L tank while *port 24 and 25* are connected to 0.75 L and 5 L tank by using ball valve switching of tank is done as per requirement. The Pneumatic test bench has in all 3 types of pneumatic lines. First two control lines for Circuits 1 and 2, secondly two input lines for Circuits 3 and 4 and finally six output measurement lines for Circuit 5 to 10. All lines have separate dial gauges with 160 mm dial diameter for measurement. These are SS bourdon gauge, glycerin filled, panel mounted. These are assembled on aluminum vertical flat surface in such a way that its orientation is perfectly straight. Input Pressure lines will have single tank with 40 liter's capacity each. Outputs of tank are through flexible hoses of total 5. These flexible hoses are connected according to the circuit layout with suitable fittings and adapter. All input lines and output lines are connected to quick connector ports with SS metal tubing and all ball valves, tanks (40L, 0.75L and 5L) are connected by using SS metallic tubing.

(i) Circuit 1st and 2nd (*Port 41 and 42*): This is primary to test the internal leakages of the valve and self cracking pressure. The air from the compressor is connected to either 0.75 liter or 5 liter air tanks through fine tuning pressure control valves. To verify

the pressure before the fine pressure setting valve a. pressure gauge is provided on the panel and to check whether the tank pressure has reached or not, the pressure gauge is provided on the panel for the respective tanks. These circuits has two options through ball valve

A. Fine setting valve (0-12 Bar).
B. Exhausting.

(ii) Circuits 3rd and 4th (*Port 11 and 12*): These are circuit to test performance of valve it is connected to 40 liter's tank through ball valve. The air from the compressor is connected to either 0.75 liter or 5 liter air tanks. To check pressure difference at inlet and c. outlet of valve, the pressure gauge is provided on the panel for the respective tanks. These circuits have two options through ball valve.

A. Closed position means no output.
B. From the main regulator (0-12.5 Bar).

(iii) Circuits 5th and 6th (*Port 21 and 22*): These are individually connected to delivery tanks 0.75 litter's capacity each (Festo SS make) and exhaust silencer through ball valve. Interchanging of tank capacity is done between 0.75L to 5L as per test requirement. These circuits will have following options

A. Closed position means no passage of air and
B. To 0.75 L tank
C. To 5L tank
D. Exhausting

(iv) Circuits 7th to 10th (*Port 23, 24, 25 and 26*): These are individually connected to delivery tanks 0.75 litter's capacity each (Festo SS make) and exhaust silencer through ball valve, these circuits will have following options

A. Closed position means no passage of air
B. To 0.75 L tank
C. Exhausting

6. Leakage checking of Joints on Test Bench and Reservoir

In leakage checking of Test Bench first all joints are checked by spraying soap water on joints, then leakage of all reservoir is checked by passing air of measured pressure and reservoir pressure is measured after period of time, finally Test Bench is ready for testing performance of valve.

(i) Joints Leakage Checking: All pipe joints leakage checking is done by spraying soap water method on joints.

Procedure for checking joint leakage test

a. Apply the pressure to all circuit by connecting input to output port directly.

Spray soap water on every joint. If bubbles are found in ferrule joints then leakage is removed by tightening the ferrules, Figure 10 shows soap water test method.

Figure 10 Soap water test method

After tightening the ferrules then also leakage is found then ferrules are removed and new ferrules are used for connections.

(ii) Reservoir Leakage Test: The delivery pressure lines with 12.5 bar pressure will be connected to reservoirs, where the drop in pressure after a period of time is measured. In leak test pressure drop in reservoir (0.75 L and 5 L) is checked after period of time; Figure 11 show image of leak testing of Test bench.

Figure 11 Leak Tests of Reservoirs

Inlet ports 41,42, 11 and 12 having pressure 12.5 bar are connected to outlet ports 21 and 22, 23 and 24, 25 and 26 result of pressure drop is given is Table 4.

Table 4 Result of pressure drop

Input Port Number	Output Port Number	Reservoir Capacity (Liter)	Pressure drop(Bar)	Time (Minute)
41	21	0.75	0.0	30
41	21	5.00	0.5	30
42	22	0.75	0.0	30
42	22	5.00	0.5	30
11	23	0.75	0.0	30
12	24	0.75	0.0	30
11	25	0.75	0.0	30
12	26	0.75	0.0	30

7. Testing of AC574 and DB21

Relay and pressure proportional valve are tested on Test Bench, the procedure for performance test of Brake system valve checking is first inlet and outlet of

valve are fixed with flexible tube which other end has push in fitting, according to testing procedure of valve, inlet quick coupling connecter is connected to *port 41 and 42* for variable pressure (0-10bar) and *port 11 and 12* for fixed pressure from line which is set on FRL (max 12 bar), outlet is connected to *port 21, 22, 23, 24, 25 and 26*.

(i) Relay Valve (AC574): In response to an air pressure signal from a control valve, the relay valve will speed up brake applications by providing rapid and precise control of a large volume of air. Relay valve (AC574) has subtypes as AC574AXY, AC574AY, AC574AK and AC574AX, for trail purpose AC574AXY is performance test is taken.

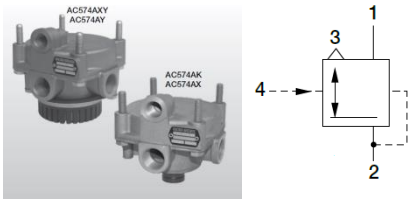

Figure 12 Relay valve (AC574)

In Figure 16 notation 1, 2, 3 and 4 indicates reservoir supply, output line (delivery line), exhaust line and signal line of relay valve. For testing relay valve port 1 and port 4 are connected to *port 41 and 42* respectively of test bench while port valve port 2 is connected to *port 21* of test bench, by using ball valve *port 21* supply is diverted to 0.75 L receiver reservoir for back pressure. By using fine setting valve pressure is adjusted of *port 41 and 42*, as maximum operating pressure for valve is 8.5 bars so *port 41* pressure is adjusted to 8.5 bars fixed pressure, port 42 pressure is varied from 0 to 8 bars outlet pressure through *port 21*is measured. Table 4.1 shows pressure applied to *port 42* and output pressure measured on *port 21*.for relay valve if pressure drop is more than 1 bar valve is rejected as per company specification

Table 5 Pressure readings of AC574AXY

Sr.No	Port 41 (Inlet Pressure) (Bar)	Port 22 (Outlet pressure) (Bar)	Pressure difference
1	0.0	0.0	0.0
2	2.0	1.9	0.1
3	4.0	3.5	0.5
4	6.0	5.5	0.5
5	8.0	7.9	0.1

(ii) Pressure Proportional Valve (DB21): A pressure proportioning valve is used to reduce the downstream (delivered) pressure by a fixed ratio relative to the supply pressure. The valve has a quick release function to speed up the exhaust of delivered air. A typical application on trucks, tractors and trailers would be to provide finer control of the service brake when using larger actuators than the maximum axle load would require. Pressure proportional valve (DB21) has sub type as DB2114, DB2115, DB2116, DB2118, DB2121, DB2122 and DB2123.

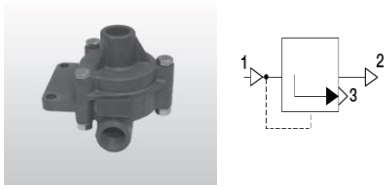

Figure 13 Pressure Proportional Valves (DB21)

Table 6 Technical Features for Proportional valve

Maximum operating pressure	10 Bar
Air port threads	M 22 X 1.5mm
Weight	0.6 kg approx

In Figure 13 shows where notation 1, 2 and 3 denotes supply, delivery and exhaust respectively, at a time two valve can be tested, *port 41 or 42* of test bench are used to give input pressure which is connected to port 1 of valve and port 2 of valve is connected to output port of bench, depending on reduction ratio different valve types are tested, maximum operating pressure is 10 bar for testing purpose inlet (supply) pressure between 0-10 bars is given to valve and output (delivery) pressure is measured.

DB2114

- Pressure reduction ratio – 2.00 : 1.00

Table 7 Pressure readings of DB2114

Sr.No	Supply Pressure (bars)	Delivery pressure (bars)	Theoretical pressure (bars)	Pressure Difference
1	2	0.9	1.0	0.1
2	5	2.3	2.5	0.2
3	9	4.2	4.5	0.3

DB2115

- Pressure reduction ratio –1.50 : 1.00

Table 8 Pressure readings of DB2115

Sr.No	Supply Pressure (bars)	Delivery pressure (bars)	Theoretical pressure (bars)	Pressure Difference
1	2	1.3	1.34	0.04
2	5	3.1	3.33	0.23
3	9	5.7	6	0.30

8. Results and Discussions

As per company standards for relay valve (AC574) series average pressure difference between inlet and outlet of valve should be less than or equal to 0.5 bars, while for pressure proportional valve (DB21) series

average pressure difference between actual and theoretical pressure should be less than or equal to 0.5 bars, and for pressure limiting valve average pressure difference should be less than or equal 0.5 bars.

(i) Result of relay valve (AC574AXY): By using pushing fitting and flexible pipe relay valve was fitted to *port 42*, different pressure was injected between0-8.5Barand outlet pressure of valve was measured by using *port 22*. Using data from Table 5 performance of AC574AXY is drawn.

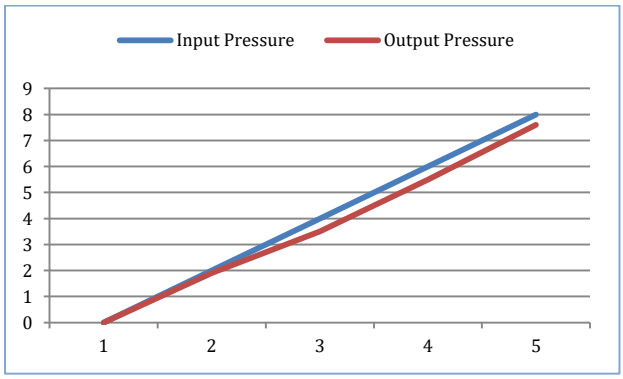

Figure 14 Performance graph of AC574AXY

The Figure 14 shows performance graph of relay valve AC574AXY, blue line indicates input pressure and red line indicates output pressure for valve.

From above graph, average pressure difference of AC574AXY =0.3 bars.

As per company standards average pressure difference for relay valve should be less than or equal to 0.5 bars so AX574AXY valve is accepted.

(ii) Result of pressure proportional valve (DB21): Five valve of different reduction ratio was tested, different pressure between 0-10 bars is given to inlet (supply) port of valve and outlet (delivery) pressure is readings measured for each valve, average pressure difference between theoretical and actual pressure should be less than 0.5 bars as per company standards.

DB2114

Using data from Table 7 performance graph for DB2114 is drawn

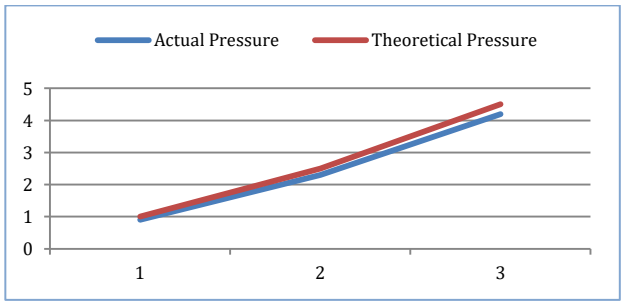

Figure 15 Performance graph of DB2114

From above graph average pressure difference is 0.2 bars. Pressure difference is less than 0.5 bars so DB2114 is accepted.

DB2115

Using data from Table 8 performance graph for DB2115 is drawn

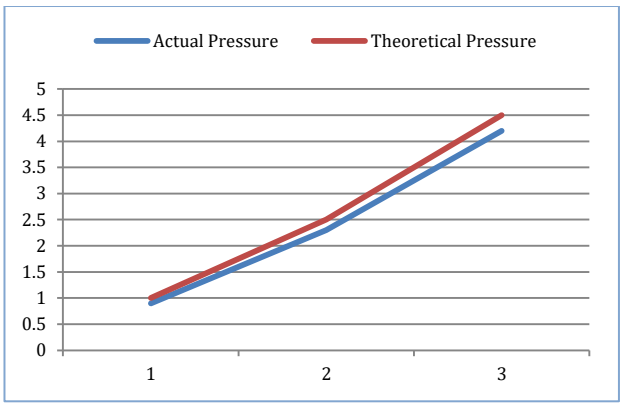

Figure 16 Performance graph of DB2115

From above graph average pressure difference 0.23 bars. Pressure difference is less than 0.5 bars so DB2114 is accepted.

Conclusion and Future Scope

The structure of Universal Test Bench is aesthetically and ergonomically designed. The pressure gauges are mounted on Test Bench at nominal height of operator for easy reading of pressure. Some of the important deductions are listed as below

- The Universal Test Bench has been successfully designed and manufactured for testing performance, pressure drop and leakages in valves of braking system.
- The Universal Test Bench operating working pressure is between 0 to 12.5 bars, all control lines and selected components are able to withstand maximum pressure up to 16 bars.
- All input lines and output lines are connected to separate dial gauges for precise measurement.
- All pressure input and output lines have been connected by SS pipes with zero leakages in all connections. Overall structure is rigid and able to withstand heavy vibrations.
- Relay (AC574AXY) and pressure proportional (DB21) valves have average pressure difference of0.3 and 0.2 which is nearly equal to 0.25 as instructed by company.

Future Scope

Test bench can be equipped with PC and complete process can be monitored by computer and if any

parameter exceeds the limits then the algorithm can control the process immediately.

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