SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 /doi:10.14445/23488360/IJME-V8I5P106

Volume 8 Issue 5, 41-46, May 2021

Development of Servo Controlled Automation For Tmc (Tandem Master Cylinder) Performance Test Rig

H.Venkatesh[#1], Dr. K. Annamalai [*2], S.Thiyagarajan[#3]

[#]*ME – Department of Automobile Engineering, MIT Campus, Anna University.*

[*]*Associate Professor – Department of Automobile Engineering, MIT Campus, Anna University. Chrompet, Chennai, Tamilnadu, India.*

[#]*Member of R&D – Department of Measurement Engineering, Wabco India Ltd, Ambattur, Chennai, Tamilnadu, India.*

Received Date: 03 May 2021
Revised Date: 04 June 2021
Accepted Date: 10 June 2021

Abstract – *The functional parameters of Tandem Master Cylinder of a braking system are evaluated through Tandem Master Cylinder Performance Test Rig.Tandem Master Cylinder ensures required pressure buildup in the hydraulic line of braking system.In existing Tandem Master Cylinder Performance Test Rig, two areas have been identified for improvement.First one is manual measurements of TMC Crack-off hole test and Piston Return Time Test.Second one is inability to achieve accurate travel ramp rate.Manual measurement of TMC Crack-off hole test is overcome by incorporating pressure and travel sensor for data measurement and also developing a new pneumatic circuit.Manual measurement of TMC Piston Return Time Test is overcome by designing and fabricating a new test fixture assembly.To achieve accurate travel ramp rate, a servo motor with inbuilt servo drive programming unit is incorporated.To interface the servo drive program with LabVIEW application for achieving the travel ramp rate and test data capturing in LabVIEW.Comparison of existing test method data and experimental new test sequence graphical data can be generate based on the results, identify the test quality improvement and accuracy.*

Keywords – *Tandem Master Cylinder, LabVIEW, Kollmorgen Automation Suite, Performance Test rig, Virtual Instrumentation.*

I. INTRODUCTION

A Tandem Master Cylinder has to be designed to provide pressurized fluid volume for braking in automobiles.It works under the principal of Pascal's law.This device is to be mounted in line with vacuum booster.For normal operation,the output force from vacuum booster is used to operate TMC which in turn generates hydraulic pressure for actuating wheel cylinder or brake caliper depending upon type of brake system(drum or disc).It has two independent circuits' viz., primary and secondary for effective braking.In case of failure in one of the circuits,the other will serve the purpose and hence partial braking will be achieved.A Tandem Master Cylinder device performance can be qualifying by performance test rig.In existing TMC performance test rig is available to test the TMC crack-off hole test and Piston Return Time test by manual operating method and manual data capturing process.To avoid the manual measurement due to human errors and improving the testing quality standard by implementating new technique in existing TMC performance test rig.In this new method of testing development can be differentiate the test quality,accuracy and test lead time.

By implementating the new concept in existing sytem,design of pneumatic circuit for crack-off test and fabrication of operating panel can be develop integrate with existing test rig.For piston return time test,new test fixture to be design for measuring the TMC input rod travel.Both real time test data capturing process done through NI LabVIEW software.The servo drive system is implementating for higher accuracy and position control with respect to the reference inputs.

Explanation about the existing test rig block diagram function.NI labVIEW application is developed for test logical sequence,parameter configuration,manual mode operation, automode operation and test data capturing operation.Servo Motor drive control inputs was connected to NI digital output module.The servo drive control program was taken by NI labVIEW application.The test data capturing was taken by NI labVIEW application parallely.All the modules like Digital input and output, analog input and output were connected to NI module chassis.In this system

all the control process for input,output and data capturing has been programmed in sequencial logic in NI labVIEW application.

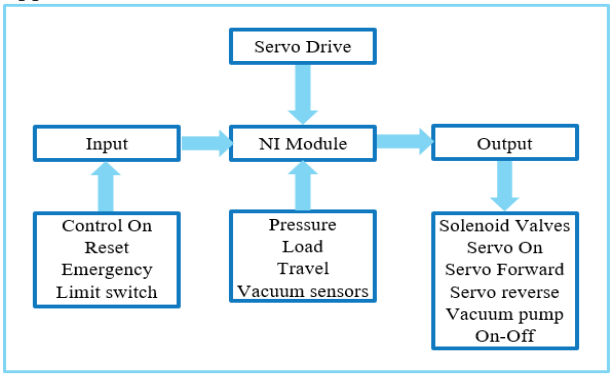

Fig 1: Block diagram of existing performance test rig

Therefore, the controlling of motor with respect to load, travel and pressure set point not able to control accurately and travel ramp rate tunning was not achieved in this system.The major point found from the existing system is delay in communication for motor control with respect to sensors.Based on this control issue, some of the test parameter was measured through manual operation.Two of the test sequence Crack-off hole Test and Piston return time test results were manual operation.

II. EXISTING TEST METHOD CONCEPT

A. Crack-off hole test

The test condition of crack-off hole test is to apply air pressure of 2±0.1 bar to TMC outlet ports (primary and secondary). Route the supply ports to container filled with water.Gradually apply stroke to the input rod and observe the stroke to the input rod and observe the stroke at which the air bubble pop out stops.The TMC input rod stroke value is manually noted by visually identifying the air bubble pop out stop condition.Therefore, human error can be vary by manual and no graphical data available for this test.Below test setup condition shown in figure 2.

Fig 2: Existing test method of crack-off hole test

B. Crack-off hole test results

Crack-off Travel in mm					
Trials	Spec.	TMC – 1 in mm		TMC – 2 in mm	
		Pri.	Sec.	Pri.	Sec.
1	1.8±0.6 mm	1.1	0.9	1.0	1.1
2		1.0	0.9	1.1	0.9

Pri. – TMC primary travel, Sec. – TMC secondary travel

C. Piston Return Time test

The test condition of piston return time test is to bleed the master cylinder with brake fluid. Traverse the piston to the ful stroke by opening the outlet ports. Close the outlet port and allow the piston to return its initial position. Time taken for full stroke to home position shall be measured. Acceptance criteria is piston should returnto home position from full stroke condition in 1.5sec maximum.The measurement of time value is noted by using stopwatch manually. Therefore, human error can be vary due to manual measurement. Unable to measure the exact time of piston return time for TMC.Below test setup condition shown in figure 3.

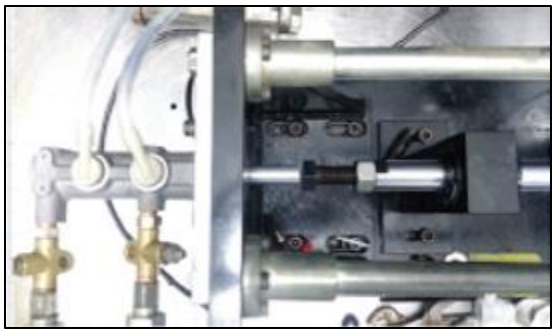

Fig 3: Existing test method of piston return time test

D. Piston Return Time test results

Trials	Piston return travel time in sec		
	Specification	TMC -1 in mm	TMC -2 in mm
1	1.5 sec	0.90	0.90
2		0.97	0.95
3		1.1	0.97

III. PROPOSED NEW TEST METHOD CONCEPT

A. Block diagram of proposed concept

The proposed concept of block diagram shown in the figure below.To avoid the human error for measurement.New servo drive inbuilt programming controller is integrated along with pressure sensor, travel sensor and loadcell also accompanied in this existing system.For achieveing accurate ramp rate and delay in the set point achievement.Therefore, more accurate test result and graphical data can be gathered with the NI system program.

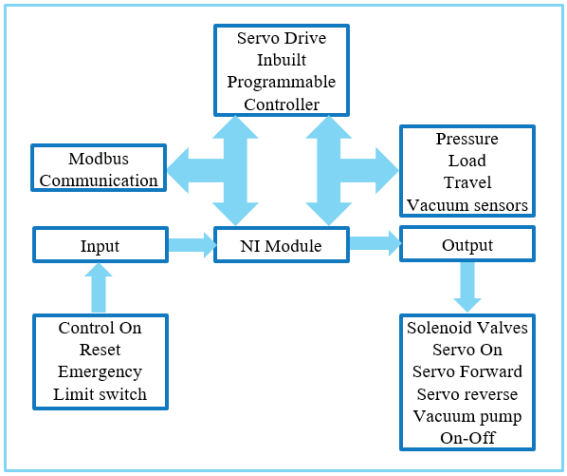

Fig 4: Block diagram of proposed concept

In this concept, test sequence program developed for both crack-off test and piston return time test.Test parameter configuration program has been included in existing program as per test condition.Dedicated kollmorgen automation Suite programming software used for controlling the servo motor drive control parameter.The transfer of test control parameter from NI LabVIEW application to Kollmorgen automation Suite via MODBUS communication.

B. Configuration of new test sequence in NI labVIEW

a) LabVIEW:It is a system development software for applications that can require measurement, testing, control, and control steps with quick access to hardware and data insights.It is a laboratory virtual instrument engineering workbench like oscilloscope, and multimeters etc.It consists of variety of tools for collecting, analyzing, displaying, and data storing as well as troubleshooting the program code.The software platform consists of front panel, elements palette, operating and display elements, block diagram, connectons, constants, control and display elements, block diagram nodes, functionality palette, and VIs functions.

b) Configuration of Test Sequence:Test parameter configuration has been created for various test sequence as per test requirements.Creating the tets sequence,entry of test parameter for servo motor forward and reverse ramp rate, travel set limit for forward and load parameter.Test parameter edit, save, save as, create, and delete option provided for user operation. Automode option is used for testing the configured tets sequence.Each test consists of several test sequence which has a unique name provided by user. This test sequence has been automately updated in automode sequence, whereas user can select the required test sequence to conduct the test.

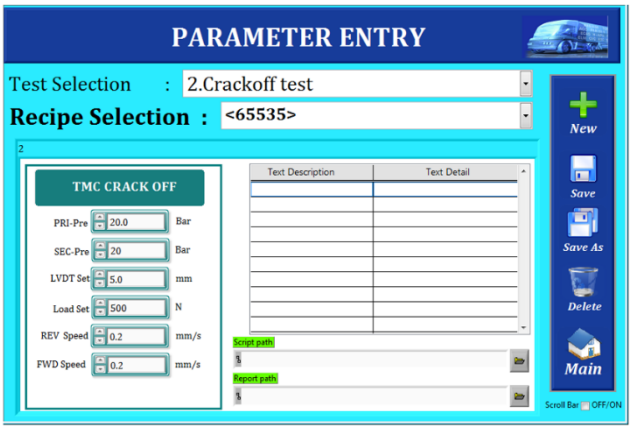

Fig 5: Crack-off test parameter entry screen

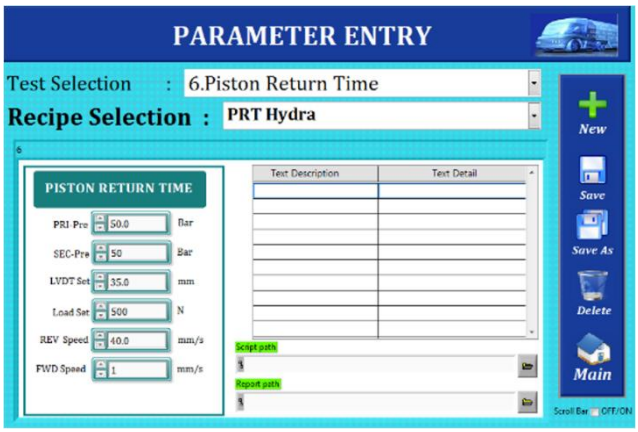

Fig 6: Piston return time test parameter entry screen

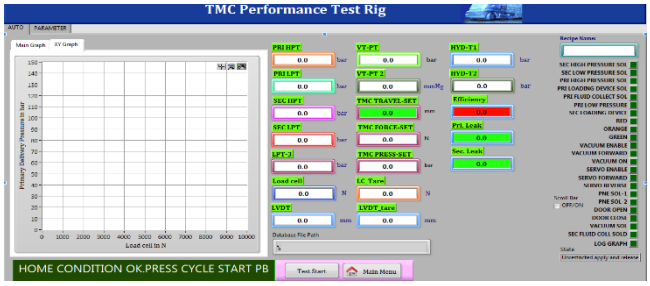

Fig 7: Automode screen

The configured test parameter entry screen figure shown in above for crack-off test ,piston return time test and automode screen.Main Navigation button provided for user can jump from current mode to mainmode screen.In Automode screen configured test sequence can select and test start option is provide to the start the test sequence. In this automode real time time data can dynamically data like senors values pressure, travel, load, and vacuum. The test running message was updated sequencing process like status of test Home condition OK, Emergency push button applied, Control ON and Reset.

C. Integration of kollmorgen automation Suite and NI LabVIEW

AKD PDMM- Programmable drive,multi-axis master used in this project. It provides an integrated servo drive and automation controller.It combines one AKD servo axis, a master controller that can supports up to seven or more addition axes, and the full automation capability of kollmorgen automation suite in a single compact package system.This KAS suite includes drives, motors,software, and feedback devices to perform fully automate and control every axis of tour entire software application.This platform chosed for this proposed concept and separate front control panel and back end program developed for servo motor drive control applications.In this drive for feedback control separate analog module provided for sensor connection based on the refernce point can control the servo motor drive and digital module also available for control signal like servo drive on, servo forward, reverse and reset. Front end operating panel is shown in the below figure.

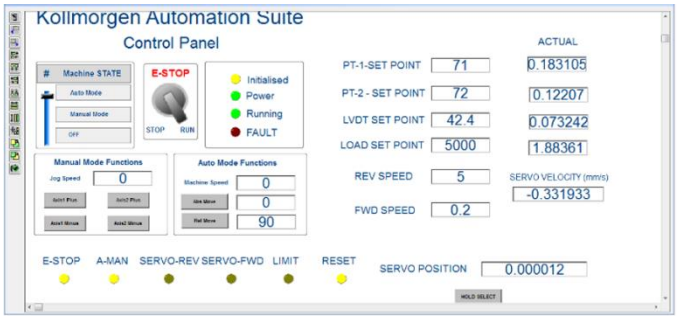

Fig 8: Kollmorgen Automation Suite – Control panel

The above figure denotes the status of drive condition like initializing, power, running, and fault.Machine state can be identify by slider bar which position it is in automode, manual, and off state.If manual mode selected jog mode is enabled for manual operation.If automode selected based on the test sequence parameter like servo forward speed, reverse speed with respect to pressure, travel, and load set point will work.Actual values of all sensors were displayed in the control panel.

IV. IMPLEMENTATION OF NEW TEST METHOD AND RESULTS

A. New test method of Crack-off test:

a) Test condition:Connect 0.2 bar air supply to the outlet ports (primary and secondary) and travel the push rod at a feed rate of 0.2±0.1mm/s and measure pressure value by pressure transducer at outlet port (primary and secondary). Once pressure reaches from 0.2 to 0.3 bar(back pressure) to measure push rod stroke and load.Acceptance criteria is 1.8±0.6mm travel, crack -off pressure at 0.2 to 0.3bar.

b) Test Setup: Below test setup shows the crack-off test operating panel.

Fig 9: Crack-off test operating panel

It consists of pneumatic circuit for back pressure concept.Digital pressure switch is provided for setting the pressure in both circuits.Flow control valve provided for setting the flow pressure when the TMC inlet and outlet open to atmosphere condition.Shut-off valve is fixed in the pressure sensor manifold for open and close purpose.Air filter with regulator 5 micron is provided for main circuit of pneumatic devices. Five litre stainless reservoir for avoiding pressure undulation.Two low pressure sensor is used in this circuit for data capturing with respect to travel.One sensor is fixed primary port manifold and another sensor is fixed in secondary port manifold.

c) Test Results:Below test result shows the crack-off travel and pressure data at which the hole presence from home position of TMC.Therefore, the graphical data gives the accurate data compare to previous test method manual entry data.Test quality standard improved and travel ramp rate is achieved.

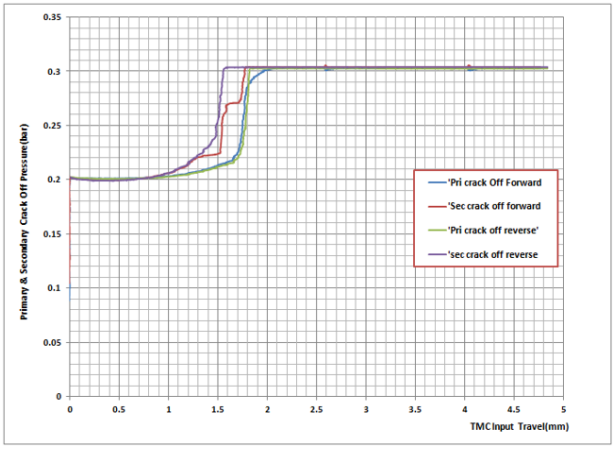

Fig 10: Crack-off test (TMC Travel Vs Pressure sensor)

Crack-off Travel in mm					
Trials	Spec.	TMC – 1 in mm		TMC – 2 in mm	
		Pri.	Sec.	Pri.	Sec.
1	1.8±0.6 mm	2.0	1.6	1.9	1.6
2		2.0	1.6	1.9	1.6

Pri. – TMC primary travel, Sec. – TMC secondary travel

B. New test method of Piston Return Time test:

a) Test condition: Bleed the master cylinder with brake fluid. Traverse the piston to the full stroke by opening the outlet ports.Close the outlet port and allow the piston to return to initial position. Time taken for full stroke to home position shall be measured.Acceptance criteria is piston should return to home position from full stroke condition in 1.5sec Maximum.

b) Test Setup: Below test setup indicates the piston return time test fixture assembly for measuring the piston travel.

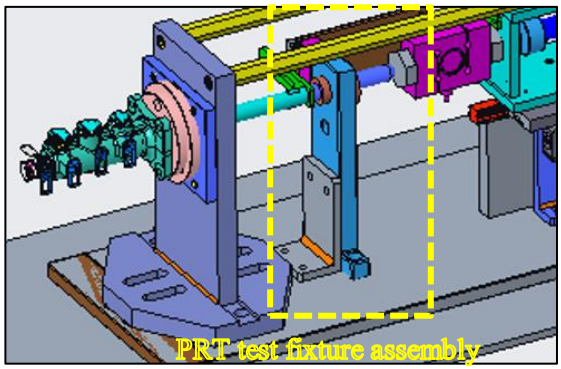

Fig 11: Piston return time test fixture assembly

The above fixture assembly consists of guide rod with ball bearing bush which is located in the guide rod mounting plate.There is no fixed connectivity between TMC piston and guide rod assembly for measuring the piston return travel.Therfore, the TMC piston real travel value can be achieved.With the help of TMC return force only the piston can travel to home position at that time guide rod can move along with this TMC force.Logic behind in this test is motor will reach its home position very fast, guide rod will move with the help of TMC return force only. Travel sensor is fixed in the guide rod assembly with the help of mounting plate.Through the travel sensor, we can measure the TMC piston travel with respect to time.

c) Test Results:Below test result shows the piston return time travel and time data to find the time taken to reach home position.Therefore, the stop watch manual time measurement method can be eliminated and improved with graphical data. Accuracy tets method and quality is improved.

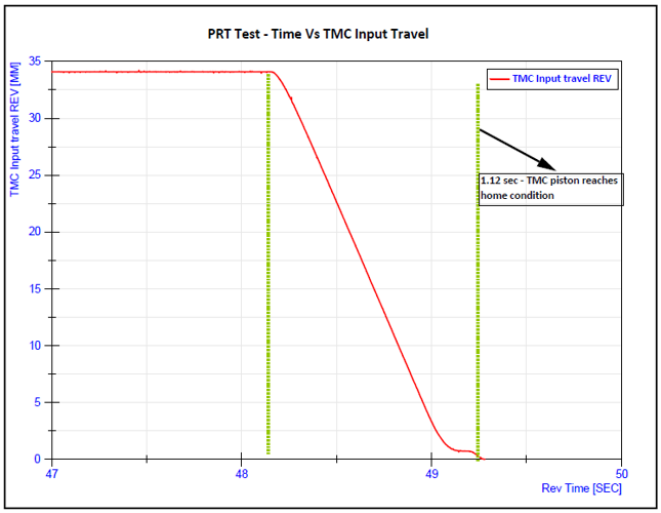

Fig 12: Piston return time test (Time Vs TMC piston return travel)

Piston return time test results	
Trials	TMC input rod return time in sec
1	1.12
2	1.14
PRT Test specification :1.5 sec maximum	

C. Benefits of PRT Test:

S.No	Before Implementation	After Implementation
1	Unable to measure the exact time of return travel	Able to measure the exact time of PRT test
2	It leads to wrong test result	Exact test result measured
3	Reduced testing quality	Enhanced testing quality
4	There is no proper setup for PRT	Developed proper test setup for PRT
5	Unable to get the graphical test data	Data acquisition program included for best data capturing
6	Manual entry of test results (not error free)	Manual intervention avoided
7	No travel ramp rate	Controlled travel ramp rate

V. CONCLUSION

This paper has introduced a new method for testing the TMC crack-off hole presence can be find easily and another new technique for finding the TMC piston return time measurement with graphical data plots.This technique can be applicable for various componets also in terms of travel measurement in critical area. Back pressure concept is used for crack-off test effectively it is working nad graphical data shows the effective and accuracy results.From this

achievement we can save the manual operating time, testing time and data analyzing time.Same time for other performance test would be improved by implementating the inbuilt servo programming system.Use of NI labVIEW application for test sequence operation and data capturing can be improve the performance as well as reliability of the system.

VI. FUTURE WORK

Number of logical test sequence will be develop for further new test requirements.Additional sensor will be include for new test concept where as analog input channels are available.Automatic report generation in LabVIEW software based on user requirements.Band width entry for test parameter in real time data analysis purpose.Vacuumbooster with tandem master cylinder will be test in future for that need to develop and design product mounting plate and extension rod.

ACKNOWLEDGEMENT

Author knowledges to Dr.K.Annamalai, Associate Professor, Department of automobile engineering, Madras institute of technology, Anna university-chennai for his valuable guidance, suggestion and immense support for the smooth progress of the project and Mr.s.Thiyagarajan, Manager, Department of product engineering, Wabco india ltd, Ambattur-chennai for allowing me to conduct project work in company facility and his continued support and sharing his valuable inputs about the project.

REFERENCES

[1] Von Thun HJ. -test bench for testing the drive train of a vehicle. Patent 4939985, USA, 1990.

[2] Yuan Y, Zhang JZ,Li YT, et al. – A novel regenerative electrohydraulic brake system: development and hardware-in-loop tests. IEEE T Vehn Techno 2018;67:11440-11452.

[3] Hon Ping Ho – The influence of braking system component design parameters on pedal force and displacement characteristics (University of Bradford) 2009.

[4] ling Jun li – Simulation and control of servo hydraulic actuators for test applications-2015.

[5] Zeng-cheng Liao, Yang li, Xian-Xu bai Design, modeling and verification of a test bench for braking simulation of ¼ vehicle-2019.

[6] Bogdan Mihai Measurement Experiment, using NI USB-6008 data acquisition-2009.

[7] Subhransu Padhee Umesh C. Pati Design of an educational laboratory for measurement and data acquisition system-2016.

[8] Aldo Sorniotti, Gianfrancesco Maria Repici Politecnico di Torino Hardware in the loop with electro-hydraulic brake system.

[9] Wolf D.Jonner, H. Winner, L. Dreilich, E. Schunck, Electrohydraulic brake system – The first approach to brake-BY-Wire Technology, SAE Technical paperseries 960991, 1996;

[10] Richard Philippe, chelles (FR), Franoois Gaffe,Bondy (FR), Bastien, Cagnac, Cramoisy (FR) electrically boosted braking system Aug 2015.

.