Design and Development of a Twin Station NRV Testing Rig

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***Abstract*— The scope of this project encompasses both the design and implementation phases of a twin-station Non-Return Valve (NRV) test rig, meticulously tailored to assess the favourable operational characteristics. The test rig is configured to execute three sequential testing procedures, each contributing to a comprehensive evaluation of the NRV's performance. The initial phase involves a leak test, designed to scrutinize the valve seating. During this examination, a controlled pressure of 0.2 bar is applied to the valve seating, and an assessment is conducted to ensure that the leakage remains well within the stipulated threshold of 0.025ml per second. The second testing operation focuses on verifying the weld integrity of the non-return valve. In this phase, a pressure of 1.5 bar is applied to the intake manifold end of the NRV. It is checked to ensure the leakage is below 0.1ml per second. The third and final testing procedure involves a vacuum test, where the manifold end of the NRV is subjected to a vacuum of 20 mmHg. Following the controlled vacuum application, the system is tested to ascertain the requisite drop in vacuum within the NRV. This process simulates the removal of pressure from the brake pedal in the booster end.**

Keywords—NRV, Twin Station, leakage, clamping

I. INTRODUCTION

The project focuses on designing and implementing the "Twin-Station Non-Return Valve (NRV) Leak Test Rig," a critical apparatus for evaluating the operational characteristics of diaphragm-based Non-Return Valves in automotive brake boosters. With three sequential tests, the rig assesses key factors crucial for the proper functioning of brake booster assemblies.

In the initial test, the valve seating of the NRV undergoes scrutiny, applying 0.2 bar pressure to the intake manifold end. Leakage is examined against a 0.025 bar threshold, ensuring compliance with stringent quality standards. This foundational test verifies the NRV's ability to maintain secure valve seating.

The second test meticulously examines weld integrity, applying 1.5 bar pressure to the intake manifold end. The system checks whether leakage remains below 0.025 bar, ensuring the welded components exhibit robust integrity. This step is critical for overall reliability and safety in brake booster assemblies.

The third test involves a vacuum simulation, subjecting the intake manifold end to 50 mm Hg of vacuum. Within a specified timeframe, it ensures vacuum pressure drops below 20 mm Hg. This real-world simulation assesses the NRV's effectiveness under rapidly reduced pressure conditions, a vital parameter for brake systems.

Failure in any of these test's results in the unequivocal classification of the NRV as faulty, leading to its subsequent discard. This stringent quality control mechanism ensures that only NRVs meeting predefined criteria for leak tolerance, weld integrity, and vacuum pressure are integrated into brake booster assemblies. The "Twin-Station NRV Leak Test Rig" project signifies a meticulous and critical endeavor to advance quality and performance standards in the automotive industry, ensuring the safety and reliability of braking systems.

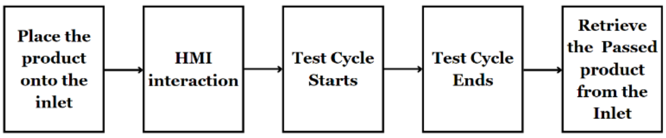

Fig 1: Block Diagram of the proposed solution

The block diagram you sent depicts a simplified overview of a product development test cycle. It outlines four stages:
Place the product onto the inlet: This represents the initial step where the product to be tested is placed at the starting point of the testing process.

Test Cycle Starts: This indicates the beginning of the testing procedure. The product is likely subjected to a series of tests designed to evaluate its performance, functionality, safety, or other relevant characteristics.

HMI Interaction: HMI (Human-Machine Interface) interaction suggests that the diagram incorporates some form of user input or monitoring during the testing process. This might involve controlling the test equipment, monitoring test results on a computer screen, or interacting with the product under test.

Test Cycle Ends / Retrieve the Passed Product from the Inlet: This signifies the completion of the testing process. If the product has passed all the tests, it is removed from the inlet, which likely indicates it is ready for further processing or shipment.

II. FLOW OF THE PROCESS

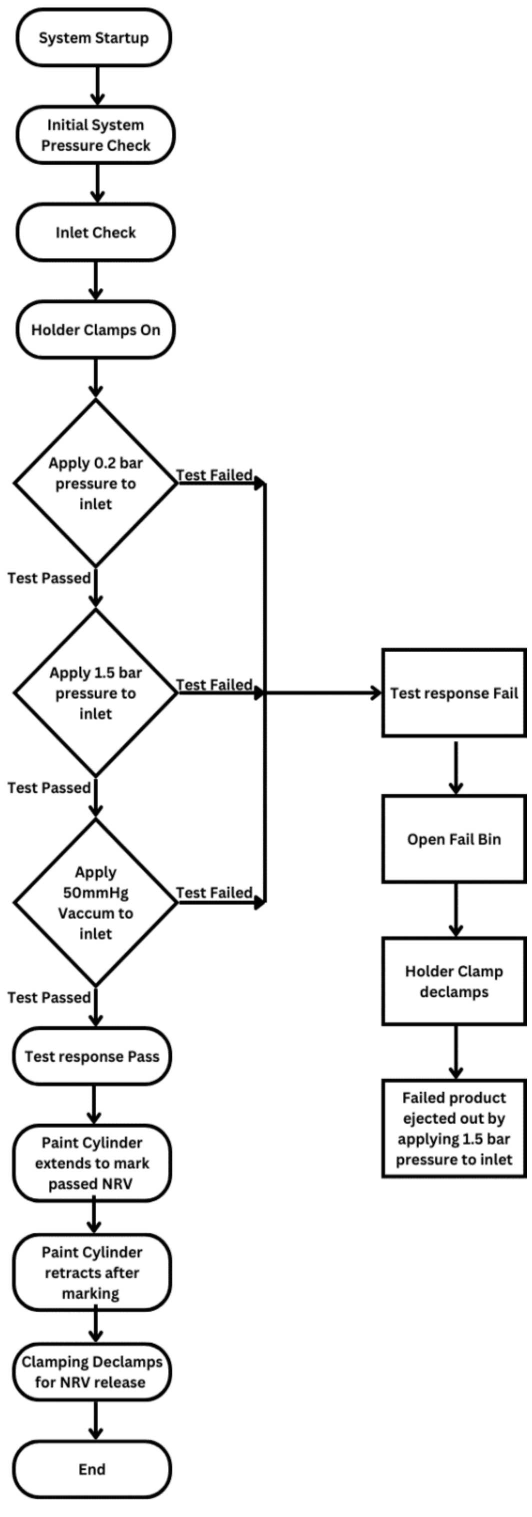

Fig 2: Flow Chart of the proposed solution

The process ensures that manufactured products meet the designated pressure specifications, guaranteeing their functionality and safety.

The pressure testing process follows a sequential flow, as outlined in the flowchart:

Initial Pressure Application (0.2 bar)

The test commences with subjecting the product to a preliminary pressure of 0.2 bar. This low-pressure test serves as an initial screening to identify any significant weaknesses.

Pass/Fail Decision

Pass: If the product successfully holds the 0.2 bar pressure, it progresses to the next stage of testing.

Fail: If the product fails to withstand the pressure (indicating leakage or rupture), corrective actions are taken:
The holding clamp securing the product is released.
Compressed air or fluid is introduced into the product at a higher pressure (1.5 bar) to expel it from the testing area. This ensures the removal of faulty items from the production line.

Second Pressure Application (1.5 bar)

Products that pass the initial check are subjected to a more rigorous test with a higher pressure of 1.5 bar. This simulates the actual operating pressure the product will encounter during its intended use.

Second Pass/Fail Decision

Pass: Products that endure the 1.5 bar pressure are deemed to have passed the pressure test. These likely proceed to subsequent stages in the manufacturing process (not shown in the flowchart).

Fail: Products that fail this test undergo the same ejection process as in step 2 (clamp release and pressurization for removal).

Process Completion (NRV Release)

The final step signifies the completion of the testing cycle for a particular product. This step likely involves:
NRV (Non-Return Valve): The "NRV release" mentioned in the flowchart refers to a non-return valve associated with the paint cylinder. This valve safeguards that paint only flows in one direction, typically towards the product being painted.
Cylinder Retraction: With the clamping mechanism disengaged (due to a pass or fail at step 4), the paint cylinder retracts, signifying the test's completion for that specific product.

The pressure testing process plays a very important part in upholding the quality and reliability of manufactured products. By incorporating this multi-stage testing procedure, we can guarantee that products meet the designated pressure requirements, minimizing the risk of failures during operation. This, in turn, enhances customer satisfaction and reinforces brand reputation.

The image you included is a schematic diagram of a hydraulic system used for pressure testing a component. The system consists of several key parts:

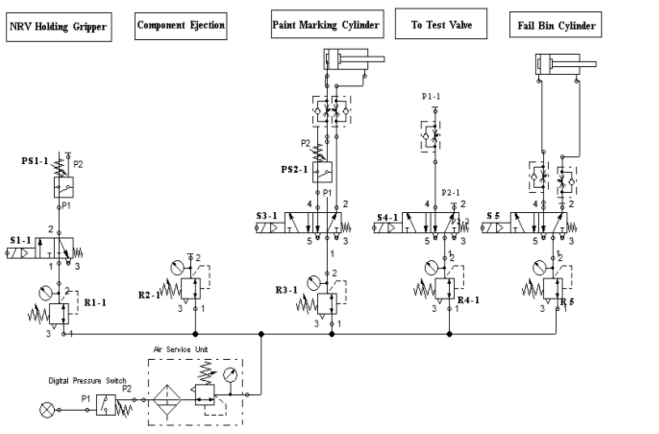

Fig 3: Actuation Pneumatic Circuit

Cylinders: The diagram shows two cylinders, likely including one for holding the component under test (NRV Holding Gripper) and another for applying paint (Paint Marking Cylinder).
Pump (PS1-1): This supplies pressurized fluid to the system.
Valves: Various valves (P1, P2) control the flow of pressurized fluid throughout the system.
Pressure Switches (PS1-1, PS2-1): These sensors monitor the pressure in the system at different points.

The process works as follows:
Fluid from the pump pressurizes the holding cylinder (NRV Holding Gripper), clamping the component to be tested.
The test valve is activated, allowing pressurized fluid to enter the component.
Pressure sensors (PS1-1, PS2-1) monitor the pressure applied to the component.
If the component fails the pressure test, it is ejected using a separate valve and cylinder (Component Ejection).

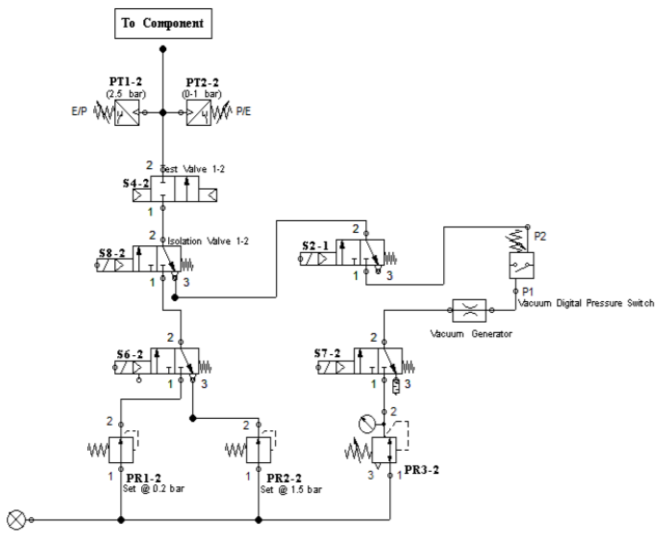

Fig 4: Testing Pneumatic Circuit

Pressure Testing Process Flowchart
The image you included depicts a flowchart outlining a pressure testing process, likely for a product that holds pressure. The flowchart details the steps the product goes through to ensure it meets the designated pressure specifications.
Process Description
The pressure testing process follows a sequential flow, likely involving the following steps:
Initial Pressure Application: The process begins by applying a low pressure to the test response. If the product fails this initial test, it is ejected for further inspection or disposal.
Higher Pressure Application: Products that pass the initial test are subjected to a higher pressure, simulating the pressure they will encounter during regular operation.
Pass/Fail Decision: Following the higher-pressure application, there is a decision point. Products that pass this test likely proceed to subsequent stages in the manufacturing process. Those that fail are likely ejected.
Process Completion: The final step signifies the completion of the testing cycle for a particular product.

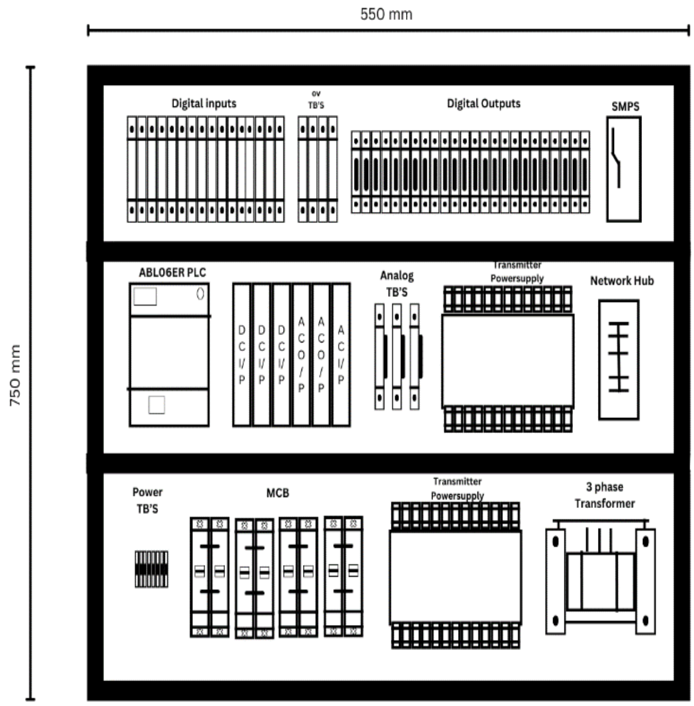

Fig 5: Electrical Panel Layout

Terminal Blocks (TBs): These are blocks that provide a connection point for electrical wires. The diagram shows several terminal blocks with labels such as “Digital Inputs” and “Digital Outputs.”
PLC (ABL06ER PLC): This is a programmable logic controller, which is a computer that is used to automate industrial processes.
Analog TBs: These are terminal blocks that are specifically designed for connecting analog signals.
Network Hub: This is a device that connects computers and other devices on a network.
AC/DC Power Supply (ACO/P): A power supply which converts the supply current which in the form of Alternating Current (AC) to a Direct Current Supply (DC) with the usage of rectifiers.

SMPS (Switch Mode Power Supply): This particular device serves as a form of power supply that exhibits remarkable efficiency in the conversion process, effectively transforming alternating current (AC) electricity into direct current (DC) electricity.
Transformer: This device facilitates the transfer of electrical energy between circuits by altering the voltage level with the usage of two sets of coils to step up or down the given supply voltage.
Transmitter Power Supply: This could be a power supply for a radio transmitter or another type of transmitter.
3 Phase Power: This refers to a type of electrical power that uses three phases to deliver power.
MCB (Miniature Circuit Breaker): This is a circuit breaker that is used to protect circuits from overload.

III. Design Calculation

Aluminum Profile Specification:
Mass = 1.63 kg/m
Tensile Strength = 230 MPa
Modulas of Elasticity = 700 N/mm
Limit of Elasticity = 145 N/mm
Yield strength = 200 N/mm

Given:
load = 15 kg

Calculation:
Square cross-section of length = 45mm
Area of cross section, A = 45mm x 45mm = 2025 mm^2
=0.002025m^2

Weight = load applied x acceleration due to gravity
= 15 kilograms x 9.81 m/s^2
= 147.150 N

Stress Developed = Force applied / Surface area of profile
= 147.15 N / 0.002025 m^2
= **72666.67 N/m^2**

Yield Strength = 230MPa
= 230 x 10^6 N/m^2

Assume: Factor of Safety (FOS) = 2

Yield Strength can be varied due to factor like manufacturing process, material imperfection and environmental condition. Factor of safety helps to account for uncertainties in material.

Stress Allowable = Yield Strength / Factor of safety
= (230 x 10^6 N/m^2) / 2
= **115 x 10^6 N/m^2**

Stress Developed < Stress Allowable
72666.67 N/m^2 < 115 x 10^6 N/m^2

Since the calculated stress is **much smaller** than the allowable, **the aluminum profile should able to withstand the load without permanent deformation.**

IV. Results

The discourse on safety standards, performance optimization, and the symbiotic relationship between innovation and reliability underscored the critical role braking systems play in shaping the automotive landscape. The current manual testing procedures for Non-Return Valves (NRVs) in automotive braking systems pose a significant challenge in terms of time efficiency and potential operational drawbacks. In response to the time-related challenges and operational drawbacks associated with manual Non-Return Valve (NRV) testing, a robust solution is proposed through the development of the "Twin Station NRV Testing Rig. This advanced testing rig integrates cutting-edge technologies, including Programmable Logic Controllers (PLC), pneumatic systems, and Manual Human-Machine Interface (HMI) Calibration, to streamline the testing process, enhance precision, and mitigate the risk of defective NRVs entering the production line. To further streamline the production line, the fail bin system includes an automatic ejection mechanism. When a defective NRV is identified during any of the three sequential tests conducted by the rig, the system triggers an automatic ejection of the defect product. This comprehensive solution not only addresses the time-related challenges associated with manual NRV testing but also introduces a versatile and precise testing rig capable of meeting the stringent quality standards demanded by the automotive industry. With manual HMI calibration and incorporating defect management measures, the proposed solution represents a significant leap towards efficiency, reliability, and adaptability in NRV testing, ultimately contributing to enhanced safety and performance in automotive braking systems.

V. Conclusion

In conclusion, The Twin Station NRV Testing Rig revolutionizes Non-Return Valve (NRV) evaluation, ensuring precise assessments through sequential leak tests and vacuum testing. By automating testing processes, the rig significantly improves efficiency, streamlining operations and reducing testing time compared to manual methods. Through its robust design and accurate data collection mechanisms, the rig facilitates continuous improvement initiatives by providing actionable insights into NRV performance and manufacturing processes. Accurate sensor integration provides comprehensive data insights, facilitating informed decision-making and continuous process improvement. Rigorous testing protocols guarantee the reliability and safety of automotive brake systems, preventing faulty NRVs from entering production. Designed to meet or exceed industry standards, the rig aligns with regulatory requirements, ensuring compliance with automotive safety regulations. With a user-friendly Human-Machine Interface (HMI), the rig ensures ease of operation, allowing technicians to monitor and control testing seamlessly. Through efficient testing processes and reduced material wastage resulting from early detection of defects, the rig minimizes environmental impact, aligning with sustainability goals and corporate social responsibility initiatives. The project provides opportunities for training and skill development among technicians and engineers involved in operating and maintaining the rig, fostering a culture of learning and expertise within the organization. This project has equipped us with a diverse skill set, fostering a deep appreciation for the complexities and rewards embedded in real-world engineering projects. Ultimately, the Twin Station

NRV Testing Rig contributes to enhanced customer satisfaction by ensuring the delivery of reliable, high-performance brake systems, thereby strengthening the company's reputation and market position.

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