TEST OF DOORS OBSTRUCTION DETECTION SENSOR

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In bus and train transport there are a number of requirements for the safety of the entrance door. For example there are requirements to provide obstruction detection within the door system. This should reverse the movement of the door should a passenger or some other obstruction restrict the doors operation. In case the door movement is realized by a pneumatic cylinder, obstruction detection can be achieved either by using a sensitive edge or by sensing of the door actuator pressure. Detection valve providing an electrical or pneumatic output signal to the door control system to initiate door opening. The pinching time of the subject or person must not exceed 1 s. This article describes the main safety requirements for door systems of intercity traffic trains and, above all, experimental verification of obstruction detection valve behaviour.

KEYWORDS

train, entrance door, safety, obstruction detection, pneumatic valve

1 INTRODUCTION

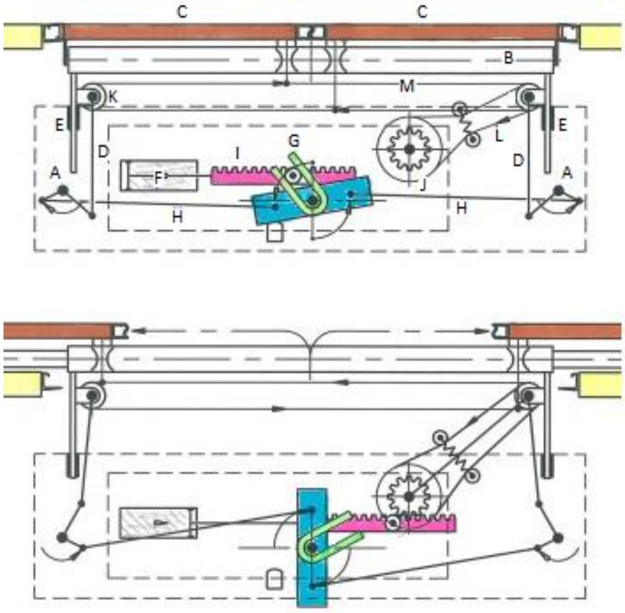
The doors of vehicles for mass passenger transport are used for the passage of people from one area to another. The doors must meet specific safety requirements of the standards EN14752: 2015, TSI PRM TSI LOC & PAS, UIC 560.

In the past the doors were simple and manually operated. With the development of technology, the doors have become more sophisticated and more automated. For this reason, these sophisticated components are now called automated door systems.

As the name suggests, the automated door systems are provided with various signalling, sensing and control devices. This not only allows greater comfort for users, but also to ensure greater safety.

There are many types of door systems at this time. We can divide them, for example, by their way of opening, by location, by number of door leafs or by way of control. This article deals mainly with doors that are used for intercity passenger train service.

Intercity trains are most often equipped with Plug Sliding Doors. The doors slides to the wagon wall after closing. This results in good door tightness and better aerodynamic properties than the sliding doors which, when closed, remains out of the plane of the wall. The door movement may be provided by an electric motor with a screw gear that converts a rotary movement into a linear movement. The trajectory of the door movement is given by the shape groove. The second possibility is to realize the movement by means of the pneumatic cylinder. The linear movement of the piston rod is transmitted to the door by a combined belt and lever mechanism, see Fig. 1. First, when the piston rod is extending, the "Scotch Yoke" mechanism (G) is rotated and the door is pushed out by a levers H, A and D. When the gear rack (I) engages in the gear wheel (J), the door opens with the help of the belts L and M.



A - lever mechanism, B - telescopic rails, C - door leaf, D, H - lever, E - linear bearing, F - pneumatic cylinder, G - "Scotch Yoke" mechanism, I - gear rack, J - pulley and gear wheel, K - pulley, L, M - toothed belts

Figure 1. Principle operation pneumatic Plug Swing Sliding door [IFE 2018]

2 SAFETY REQUIREMENTS

As already mentioned, there is a large number of door system requirements. Here is a list of the most important:

- blocking the opening while driving,
- door lock,
- door closure check,
- time delay and signaling before closing,
- avoiding start the train when the doors open,
- for independent wagons automatic closing at speeds above 3 km / h
- protection of passengers or objects against pinching.

Additional requirements :

- control from outside and inside,
- automatic closing,
- emergency opening.

In the framework of the diploma thesis **[Krajca 2016]** a pneumatic system which fulfilled all these requirements was designed. One of the thesis objectives was also to verify the protection against pinching of objects or passengers.

Below are the ways of realization of the security functions.

Light barrier

The light barrier detects the presence of objects or persons directly in door space. The disadvantage of this system is that there is no detection in the whole profile of the door. This protection is therefore used in combination with other systems.

Motion detector
This device allows detection of persons or objects in the area in front of the door. The size of the scanned space is optional. This protection against pinching is especially suitable for interior doors.
Using these two systems the punching is prevented. In case of its failure, it is necessary to pinch objects or persons only for a short time. If obstructions is detected, the closing force (maximum permissible force is 400 N) must not affect the obstacle for more than 1 s [EN 14752]. After this time, the door must automatically stop and must either:
- to fully open again,
- to open at least by 100 mm,
- be free for manual movement.
Said protection against long-term pinching can be realized in several ways, electrically or pneumatically.

Sensitive edge
It consists of a rubber profile in which two wires are drawn along the whole length. If there is deformation anywhere along the length, the wires are pressed against each other. This will switch circuit and outputting an electrical signal.

Optoelectronic sensitive edge
It is a hollow rubber profile. At one end is an infrared transmitter, the receiver is at the other end. When the profile is deformed, the light beam is shaded and the electrical circuit is disengaged.

Time relay
Protection against permanent pinching can also be implemented using a time relay, electrical or pneumatic. In both cases, if the doors are blocked and they do not reach the closed position for a specified time period, the doors will automatically open again. This protection is suitable for internal doors that are not closed with such great force as the entrance doors. Simplified pneumatic circuit is in Fig.2. Extension of piston rod and the door opening is realized by a signal from the button-operated valve 1.2. Closing of the door is realized by the help the signal from valve 1.3. In this case, the piston rod chamber is filled and a pressure signal is transmitted to the time relay 1.10. If the piston rod is not retracted for a preset time, the time relay sends the re-opening signal via valves 1.8 and 1.4. When the door closes, the valve 1.8 blocks the signal from the time relay.

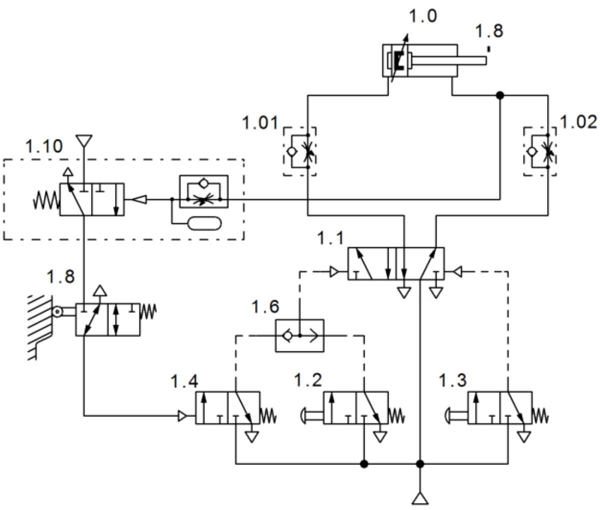


Figure 2. Time protection against permanent pinching

Detection of differential pressure on the piston
Another possibility of pneumatic protection against permanent pinching is the detection of pressure difference in the cylinder chambers. When the piston rod is retracting, the piston rod chamber is filling with compressed air whilest air from the piston chamber is exhausting. If the obstacle stops the door, the pressure in the piston rod chamber increases, the piston chamber pressure drops.
This changes the pressure difference and it can be used to detect obstruction. This can be done by a differential pressure valve with an adjustable differential pressure value. It is essentially a single acting pneumatic cylinder with adjustable spring preload which mechanically switches either a pneumatic valve or an electric switch. These elements then send a signal to open the door. The tested valve [Parker 2012] and schematic symbol are in Fig. 3.

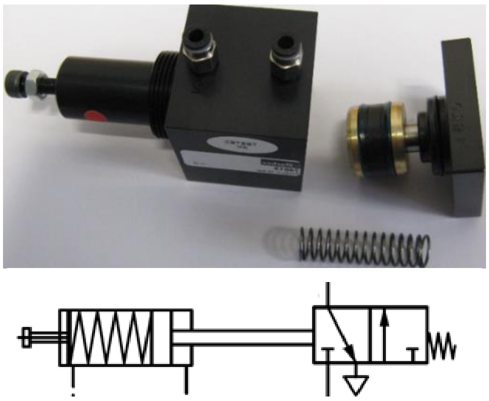


Figure 3. Obstruction detection sensor

The Fig. 4 shows a simplified circuit scheme with an obstaction detection valve. The complete circuit, which meets all the above mentioned safety features, consists of about 30 pneumatic elements. The pressure difference sensor is marked 1.10. If the sensor detects a higher differential pressure value, it sends a signal to open the door. Because the sensor would react in the end position, the signal from the differential pressure sensor is blocked by a valve 1.8 which is located 30 mm before the end position. This is in accordance with the standards. Deactivation of pinching protection also applies to electric sensitive edge.

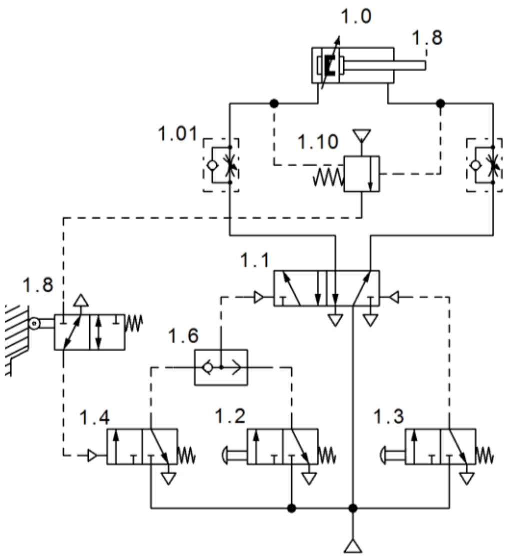


Figure 4. Protection against permanent pinching by differential valve

3 TEST OF OBSTRUCTION DETECTION VALVE

In the Laboratory of Pneumatic Mechanisms at VSB-TU Ostrava, a testing equipment for verifying the accuracy of the circuit design and mainly for verification of the obstruction detection valve function was assembled. The opening and closing of the door was simulated by a pneumatic cylinder with a diameter of 50 mm and a stroke of 650 mm. The cylinder load was realized by means of a second cylinder and a pulleys and rope system. The required load was set by the pressure value by a proportional pressure valve. First, the check the function of the control circuit has been performed. Then the setting and verification of the obstruction detection valve function followed. In Fig. 5 you can see the entire test equipment. The Fig 6 shows detail of the connection of pressure sensors and differential pressure valve.

During the valve tests, the pressure in the piston chamber p_1 and piston rod chamber p_2 was measured using Hydrotechnik PR 15 pressure sensors with a measuring range of -1 to 6 bar. Then the pressure difference was calculated from the pressure. In addition, the position of the piston rod and the force on the piston rod were measured. The velocity of piston rod movement was simultaneosly calculated from the position by the help of Hydrotchnik M5050 measuring device.

After setting the load, the deferential valve was experimentally set up. The pressure difference of 300 kPa was determined as optimal for the given cylinder, load and velocity of movement.

For verifying the valve function, a series of measurements were first performed during normal operation, when the door was not obstructed. Then there was a series of measurement of the state when the door was obstructed. Two situations were simulated. The first of them was the impact of the door to a hard obstacle, such as a suitcase. This was simulated by stopping using a plate as shown in the Fig. 7. The second situation was the simulation of a soft obstruction such as a backpack. The selected measurement results are shown in the Fig. 8 - hard obstruction and Fig. 9 - soft obstruction.

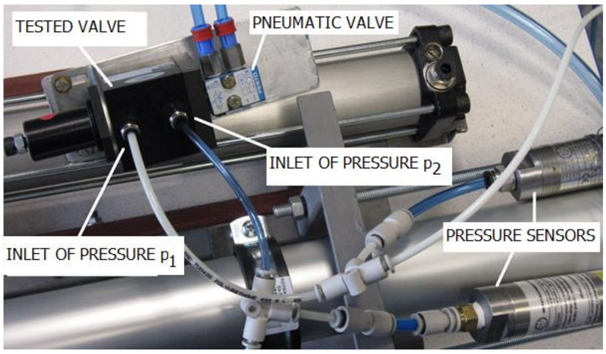


Figure 6. Connection of pressure sensors

In Figures 8 and 9, you can see the curve of the piston rod position (green curve) and the blue curve of piston rod velocity (positive values - piston rod retraction i.e. door closing). In the figures, there are also curves of pressure in the piston chamber p_1 (yellow curve), the pressure in the piston rod chamber p_2 (gray curve) and the pressure difference Δp (red curve).

The measurement results are now used for verification of mathematical model of pneumatic system.

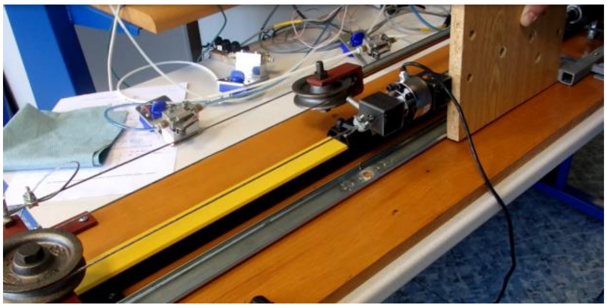


Figure 7. Simulation of hard obstruction

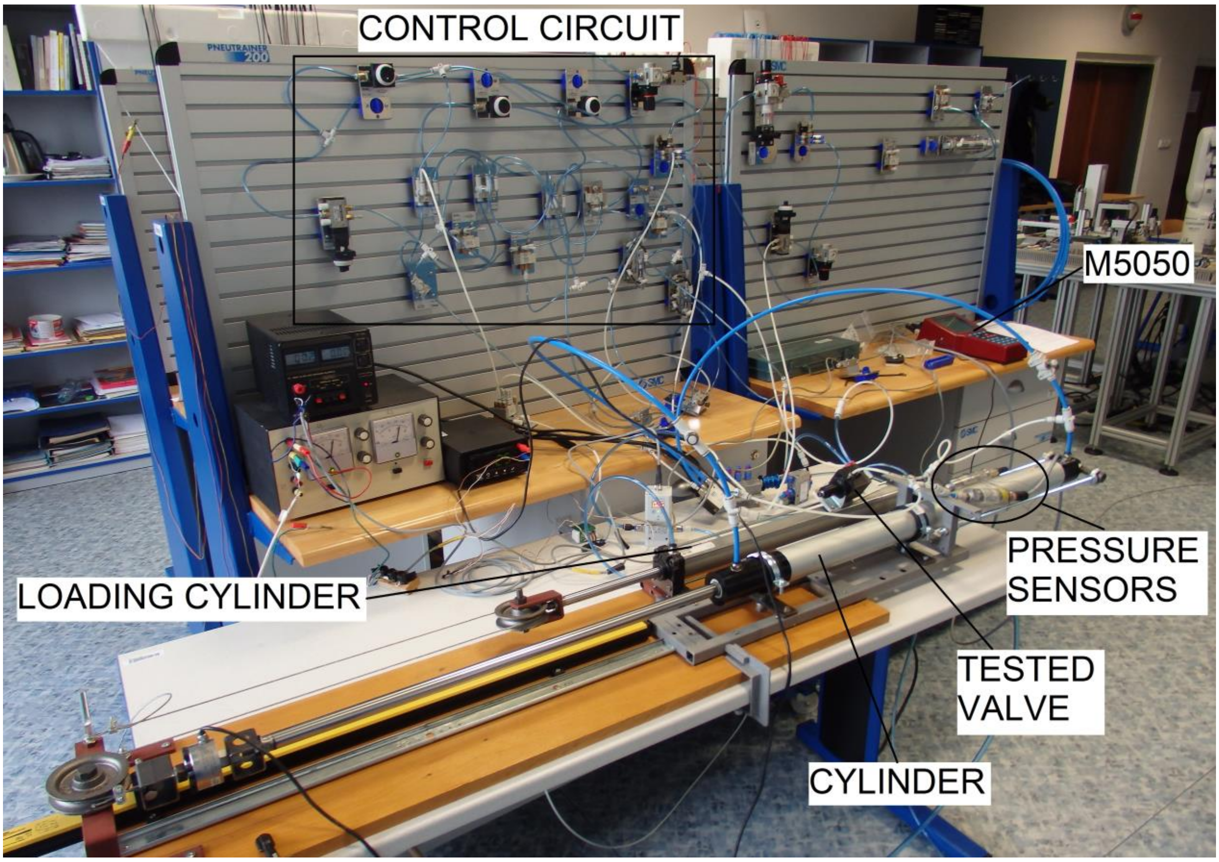


Figure 5. Test equipment

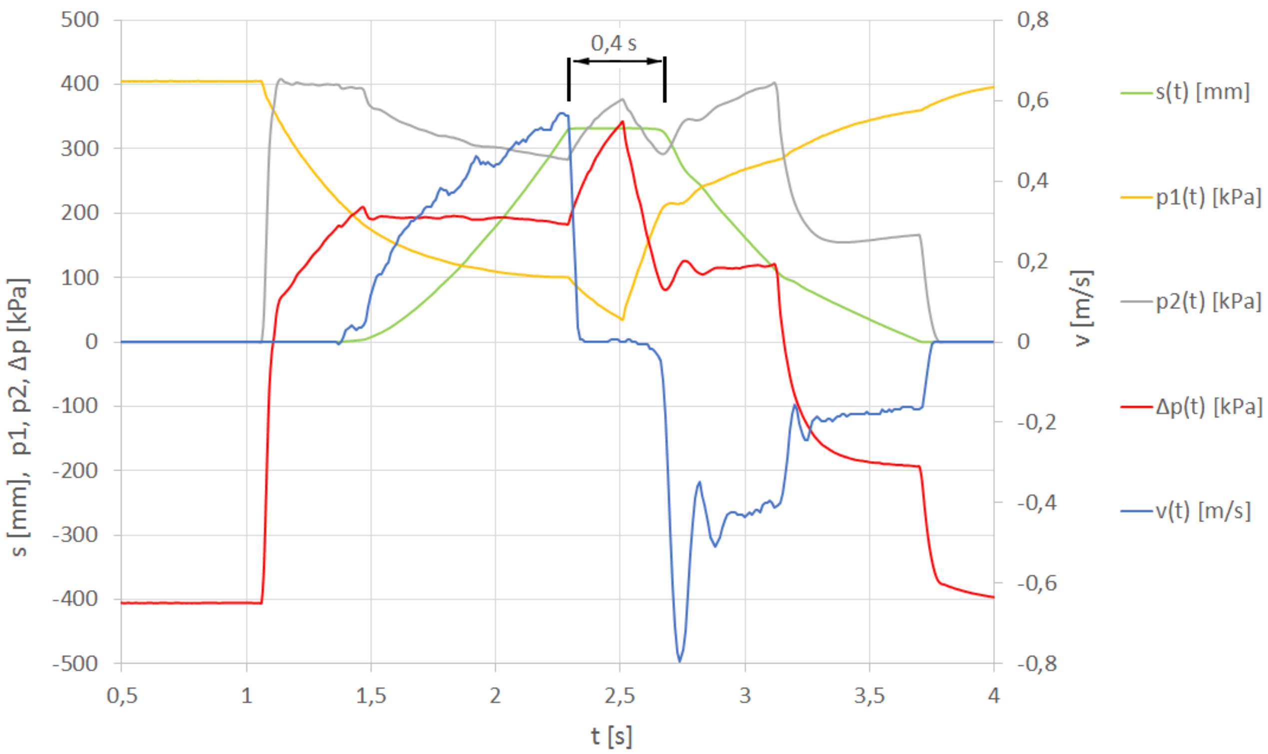


Figure 8. Measuring results - a hard obstruction

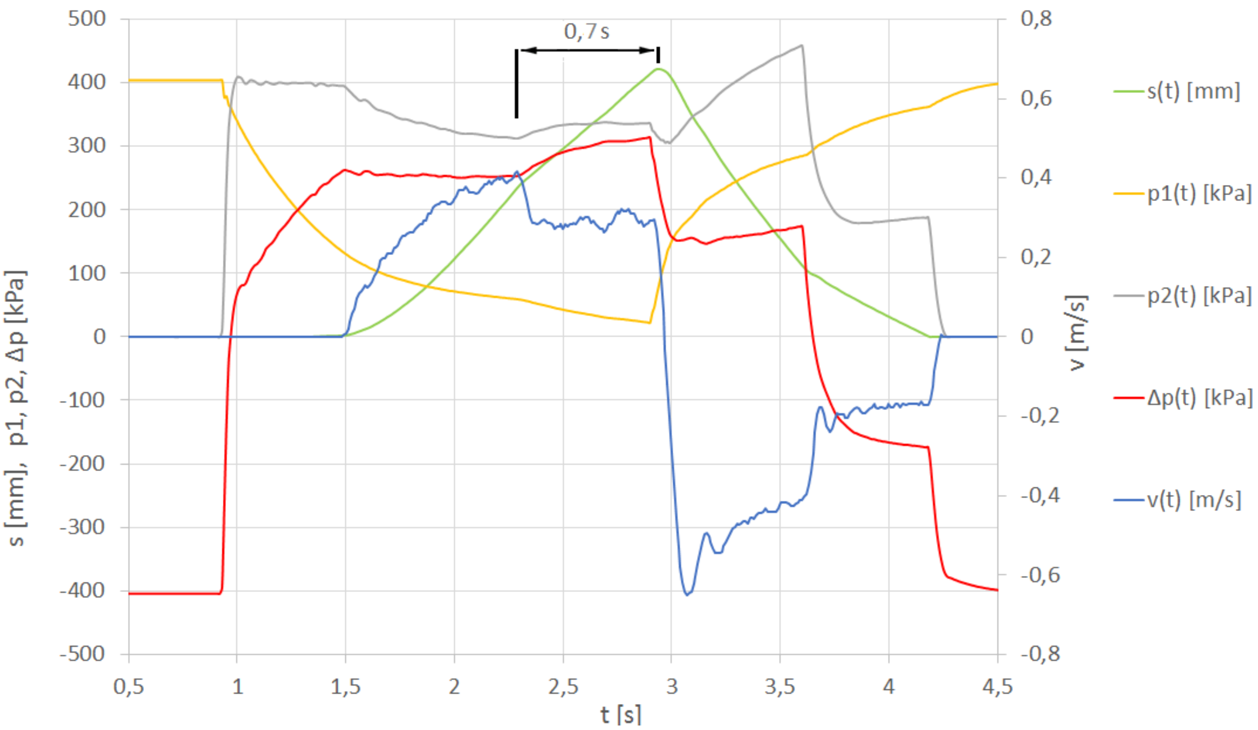


Figure 9. Measuring results - a soft obstruction

4 CONCLUSIONS

From the measurement results, it is clear that the obstruction detection valve works correctly. As noted above, the time when the person or object is pinching by door may not exceed 1 s. As shown in Fig. 8, in the event of the impact on a hard obstacle, the movement is reversed in 0.4 seconds. From the differential pressure curve (red curve) it is obvious that the valve responds for about 0.2 s. Another 0.2 s takes system response.

The Fig. 9 show the measured results of the impact on the soft obstruction. This has led to a reduction in the speed of movement. Also in this case, after a pressure differential increase above 300 kPa, motion reversal occurred. The response of the whole system in this case lasted 0.7 s.

From the above results it is clear that the obstruction detection sensor meets the requirements prescribed by the standard. It should be noted that it is advisable to supplement this detection sensor with other safety feature in order to avoid injury of passengers as much as possible.

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