Impact of the pneumatic device mechanism hysteresis on its output characteristics

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Abstract. The results of a research on hysteresis of relay valves mechanisms of different types are given in the article. When carrying out research, using special equipment, pneumatic device statistic and dynamic characteristics have been obtained. It has been brought out that profound pneumodevices diagnostics needs not only comparison of obtained output characteristics with reference ones but also hysteresis assessment, since this phenomenon effects pneumatic drive operation dynamics considerably. Implementation of hysteresis assessment procedure requires more careful studying and regulation of this phenomenon, that calls for a number of scientific studies using automated measuring complexes which allow estimating working processes’ quality as well as their effect on the tested device response time.

Nowadays there is an urgent demand for commercial transport safety since road accidents involving this type of wheeled vehicles (WV) have damaging consequences. Characteristics of particular devices (subsystems) appear to be important in this respect.

The vast majority of WV forming commercial transport are equipped with brake system pneumatic drives.

Nowadays pneumatic drive is a quite complex structure consisting of rather complex devices, sometimes, having multiple electric and electronic control, thus the diagnostics of modern brake system pneumatic drives on commercial transport has become complicated.

Profound diagnostics of brake drive pneumatic devices is carried out using values of output characteristics which are compared to the reference ones [1]. Besides, pneumatic device operability can be tested measuring hysteresis of its actuation units.

Hysteresis is a phenomenon characteristic of elastic bodies, when deformation of a body with increasing tension is less than with its reducing because of the deformation effect delay [2]. When mechanical stress is removed completely, there is a residual deformation. Being applied to pneumatic devices the phenomenon of hysteresis reveals itself in actuation units operation delay with changing the control impact degree.

We consider the definition of hysteresis on the example of a pneumatic device static and dynamic characteristics analysis. The research has been conducted within research work at Motor Transport Department of Vladimir State University named after Alexander and Nikolay Stoletovs (VLSU).
For definition of a hysteresis experimentally statistic characteristic of the relay valve 9730110010 in the "braking" and "braking-off" modes was determined. The statistic characteristic has been defined using K-245 test stand, the scheme for connecting of a pneumatic device to the stand is presented on figure 1. Measurement results are given in tab. 1.

**Figure 1.** The scheme for relay valve 9730110010 connection when determining statistic characteristic:
a, b – stand K-245 fine control valve; c, d – output pressure manometer for the fine control valve; e, f, g – switching connection; h – manometer of the measuring circuit; i – relay valve 9730110010.

**Table 1.** The results of the relay valve 9730110010 statistic characteristic determination in the "braking" and "braking-off" modes.

| Control pressure, bar | 0  | 0.5 | 1  | 1.5 | 2  | 2.5 | 3  | 3.5 | 4  | 4.5 | 5  | 5.5 | 6  | 6.5 | 7  |
|-----------------------|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|-----|----|
| "braking" mode        | 0  | 0.1 | 0.7| 1.2 | 1.8| 2.4 | 2.9| 3.5 | 4.1| 4.7 | 5.2| 5.75| 6.3| 6.85| 7  |
| Outlet pressure, bar  |    |     |    |     |    |     |    |     |    |     |    |     |    |     |    |
| "braking-off" mode    | 0  | 0.4 | 1  | 1.4 | 2.05| 2.6 | 3.1 | 3.7 | 4.3 | 4.8 | 5.3 | 5.85| 6.4 | 6.95| 7  |

The relay valve 9730110010 statistic characteristic in the “braking” (the lower line of dark area) and "braking-off" (the upper line of dark area) modes is presented on figure 2. The characteristic obtained reveals the hysteresis phenomenon: outlet pressure with the same control pressure of braking
and braking-off differs by 0,1 bar to 0,3 bar. It should be noted that the characteristic of the valve in
the braking mode corresponds to the reference one [3].

![Figure 2. Hysteresis of the relay valve 9730110010 managing piston](image)

The hysteresis on dynamic characteristics was determined when testing ABS 4006004650
acceleration valve. To increase the accuracy of hysteresis measurements in pneumatic device
mechanism the experimental data were obtained using automated measuring complex [4] created by
employees and students of VLSU Motor Transport Department.

Tests were carried out with the help of the technique described, in "braking" and "braking-off"
modes, the scheme of ABS relay valve connection is shown in figure 3.

When testing the device the dynamic characteristic of pneumatic device executive mechanisms was
determined, as well as impact of the hysteresis on response time of the whole device. It has been
established that the difference between outlet pressure values in different operation modes of
pneumatic device with the connected consumer – the brake chamber (see table 2) reaches up to 3,5 bar
with control pressure of 4 bar.

Since in modern WV pneumatic devices such ABS modulators are connected to four brake
chambers, it can be assumed that during the pneumatic device operation on a real vehicle, the
difference between outlet pressure values in different operation modes will be much greater than that
defined when processing the measurement results.

It is also established that the processes, accompanying hysteresis of the valve actuation units,
change the ABS relay valve 4006004650 response time with solenoid-controlled valve inactive in the
bracking mode (see figure 4):
- from 0,04 sec. (difference between time with the point position \( t(C_{III}) \) and \( t(B_I) \)) to 0,1 sec (\( \tau(C_{IV}) - \tau(B_{III}) \)) in the bracking mode;
- from 0,04 sec. (difference between time with the point \( \tau(C_{VII}) - \tau(B_{V}) \)) to 0,3 sec. (\( \tau(C_{VIII}) - \tau(B_{VII}) \)) in the bracking-off mode.
Table 2. Defining the difference of outlet pressures of the ABS 4006004650 acceleration valve in the "braking" and "braking-off" modes with a different control pressure.

| Control pressure, bar | Outlet pressure, bar | Difference of outlet pressures in the different modes, bar |
|-----------------------|----------------------|----------------------------------------------------------|
|                       | "braking" mode       | "braking-off" mode |                                                   |
| 0                     | 0                    | 0.4             | 0.4                                                 |
| 1                     | 0.1                  | 2               | 1.9                                                 |
| 2                     | 0.4                  | 3.2             | 2.8                                                 |
| 3                     | 1                    | 4.3             | 3.3                                                 |
| 4                     | 2                    | 5.5             | 3.5                                                 |
| 5                     | 3.1                  | 6.5             | 3.4                                                 |
| 6                     | 4.8                  | 7.2             | 2.4                                                 |
| 7                     | 6.6                  | 7.8             | 1.2                                                 |

Figure 3. The scheme of ABS relay valve 4006004650 connection when testing:

- a, b – fine control valve;
- c, d, i – measuring complex pressure sensors;
- e, f, h – switching connection;
- g – ABS relay valve 9730110010;
- j – brake chamber;
- k – plug.

The results of the research described point us to the conclusion that profound pneumatic device diagnostics requires not only the comparison of actual output characteristics with reference ones, but also the hysteresis assessment since this phenomenon considerably effects pneumatic device operation dynamics considerably.

In turn the implementation of hysteresis assessment procedure requires more careful studying and regulation of this phenomenon, that calls for a number of scientific studies using automated measuring complexes which allow estimating working processes’ quality as well as their effect on the tested device response time.
Figure 4. The ABS relay valve 4006004650 dynamic characteristic with solenoid-controlled valves inactive

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