Piezo-valves in electropneumatic positioners – proven 100,000 times over

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Intelligent electropneumatic valve positioners with switching piezo-valves have been working successfully under stress conditions in different industries for the last seven years or so. The piezo-controlled pneumatic output unit has proven so reliable and long-term stable that the intelligent devices of the second generation have been equipped with the same technology. The piezo-controlled valves have a much longer field service life in positioners than magnetically controlled switching valves. They are absolutely insensitive to magnetic fields and are oblivious to the “adhesive effect” which occurs in solenoid valves due to remanence. There is a lot to be considered in the selection of the piezo bending converter when using the piezo technology in devices for industrial applications. Problematical marginal conditions and solutions to these are described below.

1. Piezo-valves switch compressed air virtually without power

The pneumatic piezo-valves used in the electropneumatic positioners (figure 1) consist of a pre-control unit and a main switching unit.

![Figure 1: Electropneumatic positioner SIPART PS2 with piezo-valves (Siemens).](image)

The force or energy required for switching the pressurized air current of the pneumatic main control unit, i.e. the actual switching work is performed by the compressed air.
The piezo pre-control unit merely triggers the main switching unit and requires very little energy for this switching process.
In the off state (figure 2a) the spring-loaded piezo bending converter (BW) closes the operating nozzle (1). Any leaking air can flow off into the atmosphere through the chimney (2). The volume (3) below the switching converter remains pressureless and the control ram (4) is held in the top position by the spring (5) and the pressure at P whereby the air duct from P to A through the control ram remains closed.
If an electrical voltage is then applied to the bending converter, it bends up against the spring force and closes the chimney (2). Bending is caused because the upper
ceramic layer is shortened under the influence of the electrical field whereas the lower layer is lengthened. A pressure builds up abruptly in the chamber (3) through the nozzle (1) which drives down the control ram (4) and releases the air duct from P to A. The valve is then in the on state (figure 2b).

Figure 2: Functional principle of an electropneumatic piezo-valve

Legende:
BW = BC
Vorsteuersufe = pre-control unit
Hauptschaltstufe = main control unit
a) OFF state
b) ON state

2. High long-term stability due to symmetrical bimorphous carbon fiber converter

The type of bending converter is decisive for the reliable functioning and long-term constancy of the valve. For this converter which represents the actual heart of the pre-control stage, Siemens, presently the world market leader for intelligent electropneumatic positioners, chose the proven and patented bimorphous principle with carbon fiber carrier.

This switching converter has two properties in comparison with the carrierless multilayer converter (the production of which has been discontinued in the meantime) which are decisive for its use in the positioner:
- the effects of the electrical relaxation of the two piezo layers cancel each other out
- the thermally related bend is extremely slight due to the symmetrical structure

Figure 3 shows a bimorphous bending converter with connected control voltage. Since the electrical field of the control voltage acts in the upper layer in the direction of polarization and in the lower layer against polarization, the electrical relaxation effects (see section 3) cancel each other out. In addition the homogeneous and symmetrical structure of the bending converter largely avoids bending due to the
influence of temperature (bi-metal effect). Siemens supplies all versions with 100% final testing with limited temperature coefficient. This rules out an “exception”, e.g. due to a concealed inhomogeneity of the ceramic material being further processed. All finished pre-control units are exposed to the full temperature range (-30 °C to +80 °C) in the final testing. An excellent long-term stability can therefore be guaranteed.

Figure 3: Bimorphous piezo bending converter with conductive carbon fiber carrier. (1) gold layer, (2) carbon fiber carrier, (3) piezo ceramic layer (arrows correspond to polarization direction).

3. Miracle weapons against relaxation

The term “relaxation” is directly connected with the “piezo effect”. This phenomenon can be understood as a “creep behavior” or a habituation effect of the piezo material. A distinction is made between mechanical and electrical relaxation.

The mechanical relaxation occurs when for instance a bending converter is controlled with constant voltage over a longer period thus generating a constant force to close a nozzle in the pre-control unit for example. Due to the relaxation the closing force would drop continuously over time until the nozzle could no longer be kept tight. With a patented problem solution, the Hörbiger Pneumatik company in Schongau has succeeded in totally eliminating this effect: The mechanical pre-tension is not generated by electrical triggering of the switching converter itself but by a spring (6 in fig. 2) which presses the end of the switching converter onto the nozzle element (see figure 3). This means that no mechanical relaxation can occur in the first place and, since the force of the spring stays constant, a drift-related long-term effect can be ruled out.

The electrical relaxation which causes a slow repolarization of the piezo-ceramic material is avoided in the switching converter of the bimorphous type by the disturbing effect being eliminated by its symmetrical structure. Figure 3 shows that the upper piezo ceramic layer undergoes polarization and the lower layer counter-polarization. Since the electrical relaxation of the attacking spring force is always in the opposite direction in the patented structure of the pre-control unit, any remaining residual effect will always move the operating point to lower response voltages so that the efficiency of the pre-control element will generally become better in time but never worse in the case of existing residual relaxation.

With these measures the Hörbiger Pneumatik company has been able to eliminate the long-term side effects of relaxation. This means that this unit can today be used itself as an analog pre-control element which would have entailed considerable risks a few years ago.
The situation with magnetically controlled pneumatic valves in which “sticking” of the switching element can occur at low force ratios due to remanance effects is more of a problem.

4. Protection against moist compressed air

Even in well maintained compressed air systems, water may still get into the operational air due to a failure or fault in the drying system. In piezo valves of the first generation this led to occasional failures because the water caused a short-circuit in the bending converter. For several years the step switching piezo valves of the second generation used in the electropneumatic positioners are protected against moist compressed air by a patented integrated water trap. This water trap is absolutely maintenance free; the water collected in a sump independent of the installation position is blown out with every bleeding process (i.e. every second valve stroke change). This prevents moisture in the compressed air getting into the piezo pre-control elements. In the valves of the third generation installed in the positioners since the middle of this year, operation with water instead of compressed air is even possible. In pilot applications the valves were operated for days with water as an auxiliary energy medium. In these pre-control units the bending converter is surrounded additionally by an elastomer seal which provides a full seal against water, oil or other foreign media. Magnetically operating pre-control elements have never been able to achieve such a resistance.

5. Summary

Intelligent electropneumatic positioners are so well received on the market because they guarantee maximum plant reliability due to a long and successful operating experience with the piezo controlled main switching unit. These piezo valves specially developed for the harsh industrial environment stand out from other technologies by a high environmental resistance. This applies particularly for temperature fluctuations, moisture, pressure fluctuations and due to their small moving masses for all kinds of vibrations. The production technique which has been increasingly improved over recent years today guarantees maximum quality and long-term stability.