Development of a New 5 mm Solenoid Valve with a Rocker Type Armature

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Abstract

For solenoid valves with an overall width less than 10 mm also rotationally acting functional principles become more significant as a supplement to translatory armature movements. Already at the beginning of the 90s Magnet-Schultz has developed a 5 mm solenoid valve on the basis of a rocker armature (rotationally acting). The present patented design represents a consequently continued development with the following targets: Performance-oriented magnetic circuit with double coil, reduction of the swelling behavior of the sealing nipples, sealed overmoulding of the magnetic coil, integration of manual override and media separation.

KEYWORDS: rocker armature, media separation, overall width, coil

1. Introduction

Like all technology sectors also the development of pneumatic solenoid valves is marked by keywords as performance optimization, size reduction and functional integration in the last few decades. The historically established design of the magnetic circuit consisting of a cylindrical coil, a clamp which can be produced by means of stamping as well as of a cylindrical core and armature has become accepted on a large scale. The translatory movement of the cylindrical armature may be used ideally for presentation of the pneumatic function “opening and closing of a section”. Integration of sealing elements is possible.

In addition to the continued development of the technical data as well as miniaturization also cost aspects have been debated. By increased assembly automation and rational organization of parts production with increased quantities this aspect could be taken into account.

If the size is further reduced, components which are manufactured by means of machining will, however, reach their limits in respect of technology and manufacturability. As feasible alternatives could hardly establish themselves on a large scale in the field of alternative valve technologies such as microsystems technology, various applications still exist in this sector for the classical magnetic operating principles. For a successful implementation and consideration of various requirements regarding pneumatic as well as electrical performance, service life and production costs a critical examination of the valve construction principally used up to now is necessary.

For this reason Magnet-Schultz has taken up the development of its 5 mm solenoid valve with rocker armature, U-frame and square coil which have been existing since the 90s and has enforced the repeated progressing under current assumptions (**Figure 1**). The following chapters point out the basic new design which goes well beyond the scope of a detail optimization. The technical data are as follows:

- function 3/2-NC-valve
- rated flow 8 l/min
- pressure range 0…8 bar
- admissible leakage 0,5 l/h
- rated voltage 24 V DC 10%/-15%
- control by PWM with Peak&Hold
- actuation performance 0,7 W, holding performance 0,1 W
- temperature range -5…+50 °C
- protection class IP40 according to DIN EN 60529
- service life 100 million switching cycles

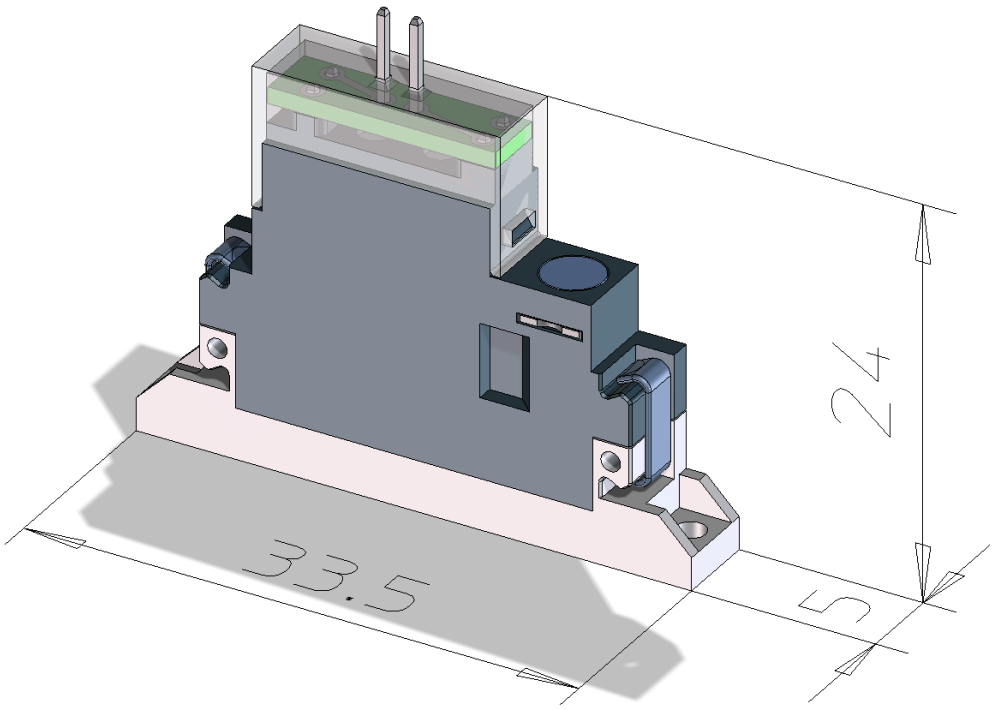

Figure 1: View of the 5 mm-valve

2. Functional Structure with Performance-oriented Magnetic Circuit

The overall width of 5 mm gives the main dimension for a copper coil with iron core. In order to achieve a reasonably usable magnetic force under these conditions under consideration of the admissible electrical performance, the magnetic circuit has been designed in form of a stampable U-frame with a winding for each core. Thus a relatively large winding window could be realized which - compared to a classic design in form of a single coil – allows the reduction of the actuation power by half. The assembly frame with coil will be plastic coated. The electrical connection is realized by means of a circuit board.

The constructional design is shown in **Figure 2**.

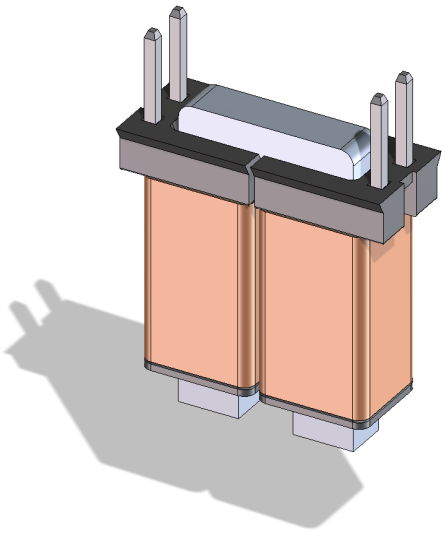

Figure 2: Design of the coils incl. frame

The armature holder is an injection moulded part. The armature plate which is produced by stamping is clipped into the armature holder. The efficiency of the iron circuit shown in simplified terms in Figure 3 fulfills the following design principles.

- Required magnetic force at nominal width of 0,5 mm and pressure range 0…8 bar FM=0,32 N
- FEM-calculation of the torque at rotation angle a1=2°
  M1=6,2 Nmm => F1=0,6 N
- FEM- calculation of the torque at rotation angle a2=3°
  M2=3,6 Nmm => F1=0,35 N

As, from the design point of view, a rotation angle of 1° already ensures the opening stroke of 0.125 mm at least necessary from the pneumatic point of view, the theoretical interpretation shows a sufficient force reserve in relation to the real implementation (**Figure 3**).

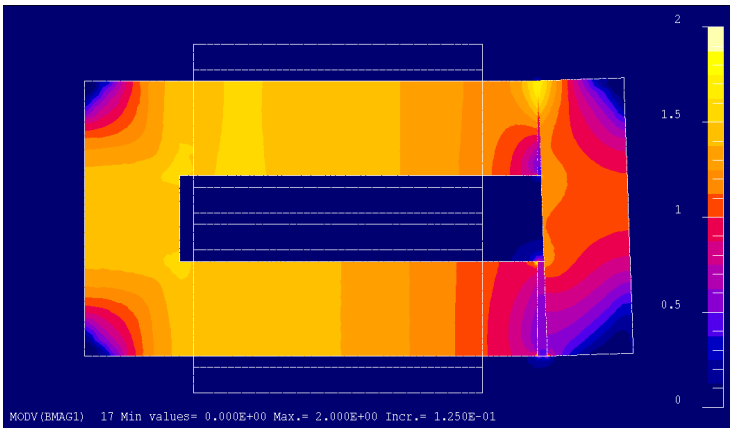

Figure 3: Simplified illustration of the iron circuit

The torques determined per FEM calculation are summarised in **Figure 4**.

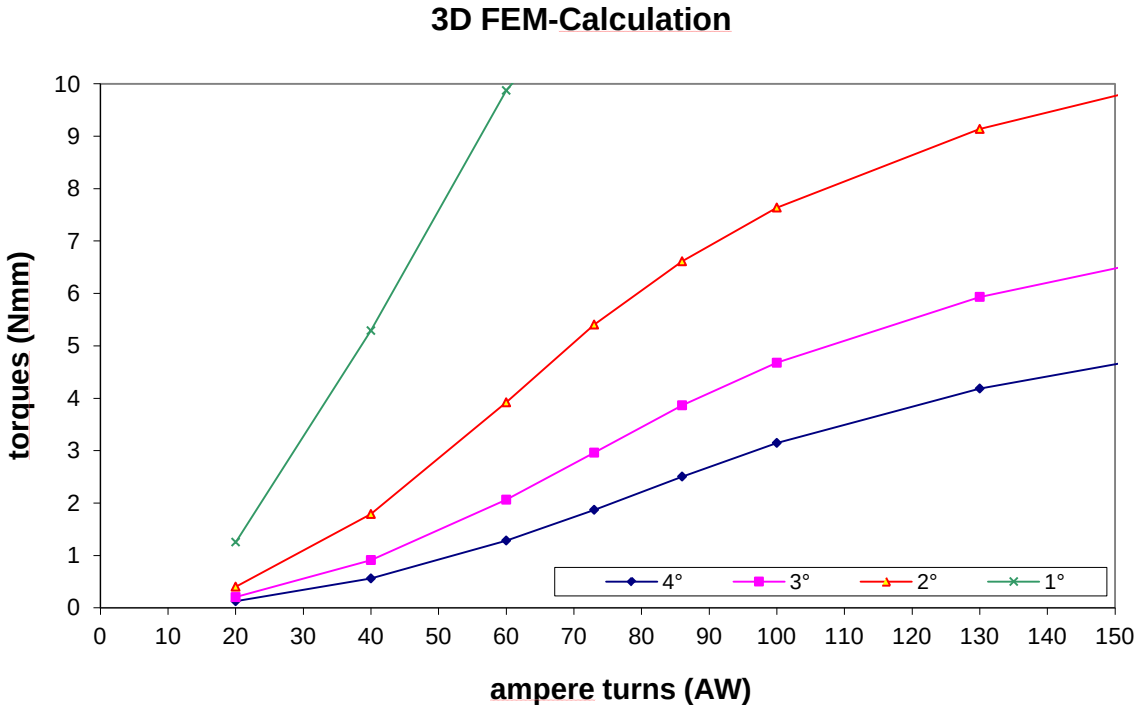

Figure 4: Results of the 3D-FEM-calculation

The sealing nipples are also clipped into the armature holder. The plastic valve body forms the outline with the associated nozzles and the counter bearing for the armature body. The manual override acting with return spring is acting in a mechanical way on the part of the armature holder shown on the right. Valve body and coil are fixed to each other by means of metal clamps. The functions of the valve are shown in **Figure 5**.

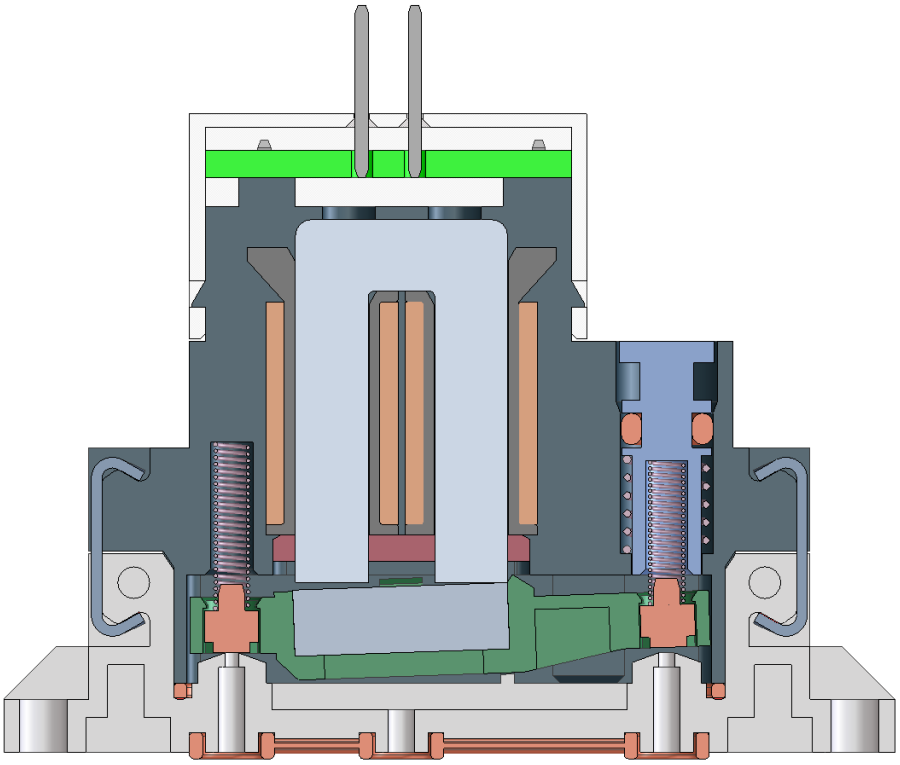

Figure 5: Function display

3. Optimized Design of the Sealing Function

The tightness of the valve function is realized by the ideal design of the sealing nipple in connection with the opposite nozzle. The increasing requirement regarding minimum leakage for valves with classic design results in the fact that the ideal alignment of the nipple towards the nozzle as well as the swelling behaviour of the nipple represents the decisive functional parameters. With the implementation of this valve principle by means of rocker armatures these aspects should be continuously improved. The detail display in **Figure 6** shows the solution (statement).

The nipple is simply clipped into the armature holder. By the clearance between armature holder and nipple the swelling both in radial and in axial direction is possible in a harmless way. The vulcanized construction principle used for cylindrical armatures results in a critical effect on the armature stroke during swelling and therefore it is effectively avoided in the innovative construction. .

Furthermore a spring has a direct effect on the valve nipple. So the nipple can level itself on the nozzle. Angular misalignments as may occur with vulcanized solutions are compensated by this.

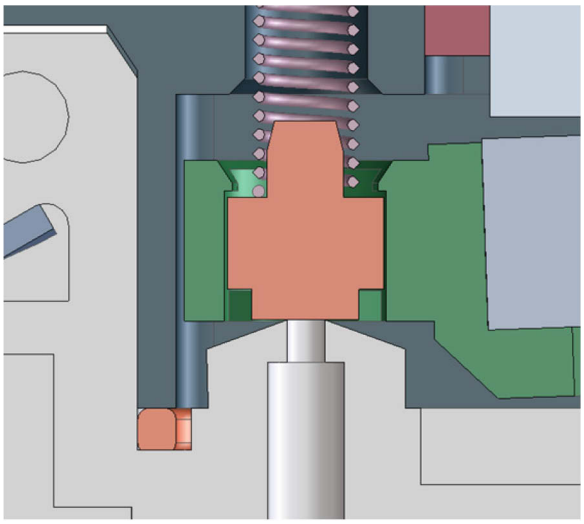

Figure 6: Design of the sealing function

4. Leak-proof Moulding of the Magnetic Coil

The valve consists of the 3 main assemblies: magnetic frame, armature and valve body. The connection between the magnetic frame and the valve body as well as the external connection to a valve plate are sealed by means of elastomer elements. The basic construction using a clamp creates a rectangular cross section. Considering the construction with a classic, cylindrically designed valve the challenge of sealing the magnetic frame is made clear. In the conventional case an O-ring or a laser-welded tube is sufficient to realize the tightness towards the outside. In the present case a sealing must be made during the moulding of the clamp including the assembled coils.

5. Integration of a Manual Override

Already for overall widths of 10 mm the realized miniaturization results in large manufacturing challenges in the conventional valve construction in respect of the use of plastic parts within the necessary close tolerance classes. The manual override has to meet several partly contrary requirements whereas here an O-ring, the actual manual override tappet, the installation cavity as well as a return spring are cooperating as tolerance partners. For example the O-ring joint e.g. can be interpreted conservatively, so tightness is firmly guaranteed. The statistical tolerances of O-ring and associated groove, however, result in unacceptably high actuation forces so that the positioning spring cannot push the manual override tappet automatically anymore. This means that in the classical valve design with an overall width less than 10 mm a reasonable design of the manual override is not possible.

Contrary to the prior versions the presented rocker armature principle allows a considerably simplified integration of a manual override (**Figure 7**). Also for overall

width of 5 mm O-ring and spring are individual components which can be manufactured with reasonable effort and in justifiable tolerance class.

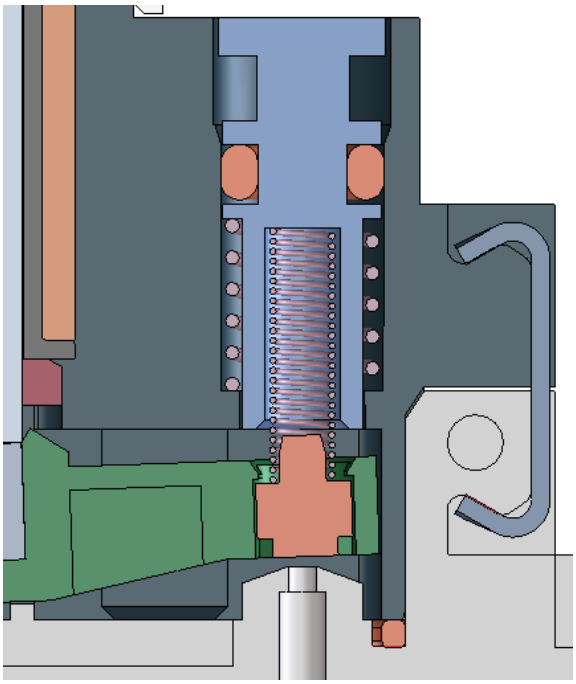

Figure 7: Integration of a manual override

6. Integration of a Media Separation

The valve construction offers the possibility to insert a media separation by integration of an elastomer membrane (**Figure 8**). To this the installation space below the armature is sealed by means of an elastomer element. So this opens up opportunities in medical technology and process industry.

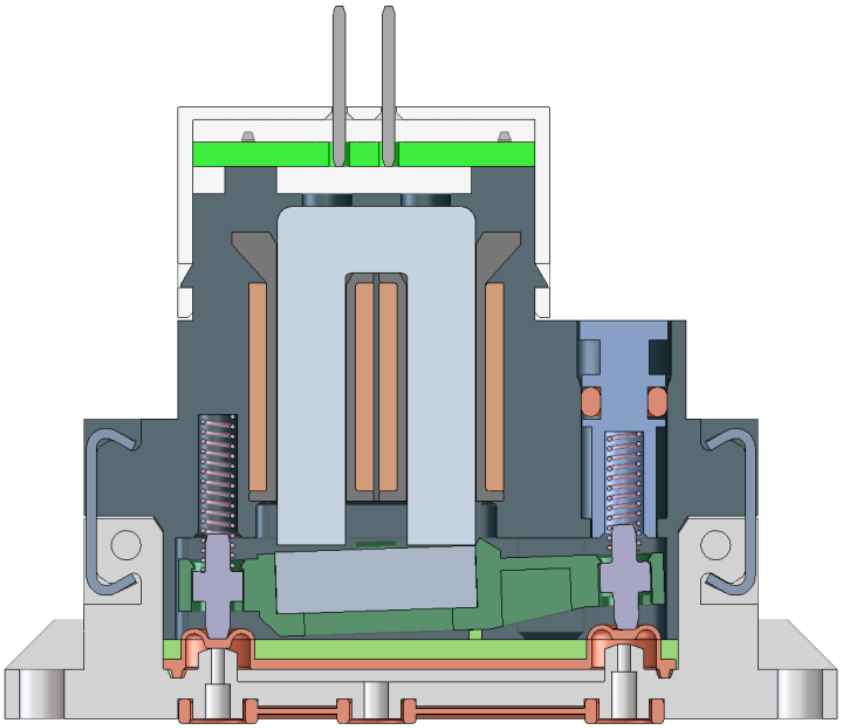

Figure 8: Integration of separating membrane

7. Summary

With advanced miniaturization of the installation size of pneumatic valves the concepts based on classic production and assembly procedures start to reach their boundaries of feasibility. For this reason Magnet-Schultz has taken up again and fundamentally revised its rocker armature concept of the 90s. The presented design shows the use of economically producible single components with simultaneously optimized power consumption and very good pneumatic data. Additionally inherent disadvantages of the valve constructions could be reduced as e.g. the negative impact of the swelling behaviour on the valve function.

With valves having an overall size of 5 mm all necessary functions as well as service life requirements could be proven and production experience could be gained in the course of a pre-series. The positive characteristics of the valve allow a reasonable enlargement of the concept to other sizes. The integration of a media separation is planned as enlargement of the application possibilities.