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Sizing of Compression Coil Springs Gas Regulators Using Modern Methods CAD and CAE

This paper presents a method for compression coil springs sizing by gas regulators composition, using CAD techniques (Computer Aided Design) and CAE (Computer Aided Engineering). Sizing is to optimize the functioning of the regulators under dynamic industrial and household. Gas regulator is a device that automatically and continuously adjusted to maintain pre-set limits on output gas pressure at varying flow and input pressure. The performances of the pressure regulators like automatic systems depend on their behaviour under dynamic operation. Time constant optimization of pneumatic actuators, which drives gas regulators, leads to a better functioning under their dynamic.

Keywords: *helicoidally spring, CAD, CAE, simulation, finite element*

1. Introduction

Pressure controller for natural gases are pneumatic devices, which made automatically and continuously adjusting the output pressure of the gases from the regulator. However, this pressure regulator maintains the predetermined limits, regardless of changes in input pressure and gas flow. Pressure regulators are therefore pressure automatic control systems, in closed circuit, and its structure systems whose operation is based on adjustment law after deviation and compare. In figure 1, is shown the structure of a pressure control system, specific pressure regulators.

Components of control systems are common to any control system, similar to electrical automatic control systems. Electrical control and controlled sizes have been replaced with pressure and displacement magnitude comparator and the actuator.

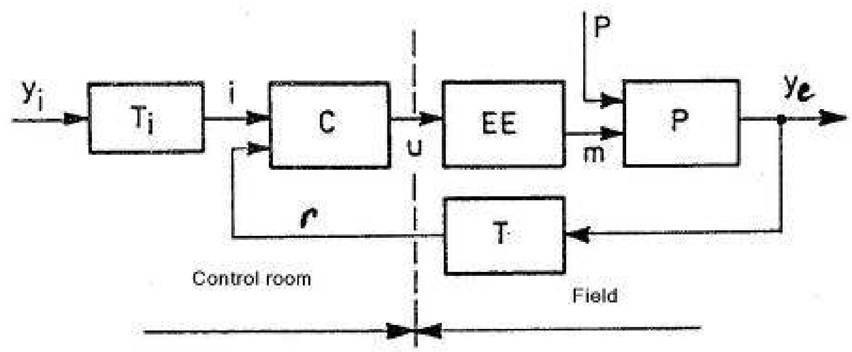

Figure 1. Control system of gas pressure regulators

Where:
P is process
C - regulator;
EE - actuator;
T - transducer;
T_i - input transducer;
ye - size output;
yi - prescribed value for y
r - size of the reaction;
i - input size;
u - control;
m - size of execution;
p - disturbance.

A pressure regulator scheme is shown in figure 2 where are detailed the components too. From figure 2 and 3 it is noted that the input size into the actuator (servo controller) is currently the u command that usually is a control pressure P_c and the output size is the pressure P_2 and the flow Q [1]. At changing the u order , respectively the pressure Pc sectional area crossing changes (flow) of the shutter 5 and seat 6 and leads to pressure variation P_2 and Q flow through pressure regulator. Pressure regulators are composed of two parts, the actuator S and body control OR.

Actuator S fitted and body control adjusting to the OR-type pressure regulators is pneumatically. Actuator S equips and controls regulating body OR, of the pressure regulators is pneumatically. Mechanically, the actuator S called servo controller, is a pneumatic motor.

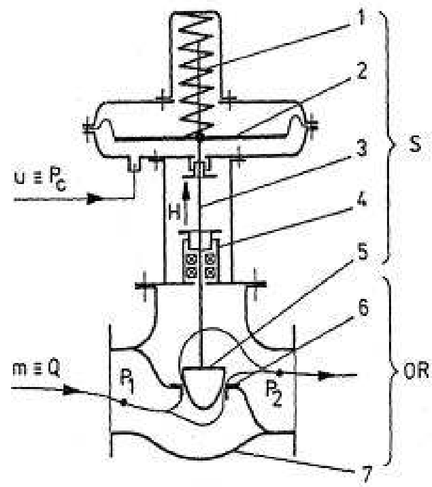

Figure 2. Diagram of a pressure regulator

Where:

S is the actuator;
OR-setting body;
1 - spring;
2 - disc membrane stiffening;
3 - win;
4 - sealing system;
5 - shutter;
6 - chair;
7 - body.

He is ordered by u size, which is the control pressure, PC, pressure coming even from the gases under regulation. Pneumatic engines are engine displacement because realizes the moving of the main active component, H - rod 3, with help of the pressure of the input gases, PC. Gases which enter in a closed compartment, of limited volume, following an increase or decrease in static pressure (PC), lead to an increase or decrease the volume. This change of volume moves the membrane with stiffening disks. Movement is tracked by the spring 3, which deforms elastic. Hence the importances of the control spring 3, which by his technical and structural characteristics, influence directly and immediately the quality control process gas.

Figure 3. Real pressure regulator – section of pressure regulator

Natural gas pressure regulators are equipped with regulating bodies and pneumatic actuators and are an automatic adjustment of which dynamic mathematical model is given by relations (1) and (2).

$$a_2 \frac{d^2 \Delta H}{dt^2} + a_1 \frac{d\Delta H}{dt} + \Delta H = b_1 \Delta Pm + b_2 (\Delta P_1 - \Delta P_2) \quad (1)$$

$$a_s \frac{d\Delta Pm}{dt} + \Delta Pm = \Delta Pc \quad (2)$$

where the differential equation (2) was written in relation to possible deviations of the control gas pressure.

Assuming:

- Time constant $a_2 = \frac{m}{k}$ of equation (40) is low and can be neglected ;
- Variation in time of pressures $\Delta P_1(t)$ and $\Delta P_2(t)$ are constants, and the b_2 coefficient of amplification product will have a negligible value (insignificant).

Based on these assumptions and technical considerations, the system of relations (1) and (2) shall have the following form:

$$a_1 \frac{d\Delta H}{dt} + \Delta H = b_1 \Delta Pm \tag{3}$$

$$a_s \frac{d\Delta Pm}{dt} + \Delta Pm = \Delta Pc \tag{4}$$

From equation (1) results as of equal value:

$$\Delta Pm = \frac{1}{b_1}\left(a_1 \frac{d\Delta H}{dt} + \Delta H \right) \tag{5}$$

and equation (5) is inserted in equation (2), resulting:

$$\frac{a_s}{b_1}\left(a_1 \frac{d^2\Delta H}{dt^2} + \frac{d\Delta H}{dt} \right) + \frac{1}{b_1}\left(a_1 \frac{d\Delta H}{dt} + \Delta H \right) = \Delta Pc$$

$$a_1 a_s \frac{d^2\Delta H}{dt^2} + a_s \frac{d\Delta H}{dt} + a_1 \frac{d\Delta H}{dt} + \Delta H = b_1 \Delta Pc$$

$$a_1 a_s \frac{d^2\Delta H}{dt^2} + (a_1 + a_s)\frac{d\Delta H}{dt} + \Delta H = b_1 \Delta Pc \tag{6}$$

This second order differential equation (6) represents the mathematical model, which expresses relatively accurate, dynamic pressure regulators equipped with pneumatic diaphragm actuators.

2. Simulation using CAD and CAE techniques

Next is presented a simulation performed with CAD and CAE techniques, on applications appearing on the helical compression spring, the composition of the pressure, RPA3-50, with application SolidWorks 2009 [2]. These simulations determine the stress, strain and displacement that occur at the request of the spring, by applying pressure on the membrane order of the controller, and were treated with a concentrated force applied to the longitudinal axis of the spring, inverted. The results obtained were compared with those determined by calculation to be optimized helically spring, to reduce the time constants and increasing the controller gains [3], [4].

Helically spring optimization will be achieved by changing the size, form of construction, the spring material, and simulate deformations, which is subject to it, according to amendments being placed on the bow. Simulation methods using finite element method is accurate and lead to the development of modern and very realistic simulation models [6], [7]. To obtain such important reduction: time required design, experimental determinations, materials and energy consumption. The figures 4, 5, 6, 7 presented simulated model of a gas regulator type RPA3-50 equipped with normal spring and stress, the strain and the displacement spring, under request. Figures 8, 9, 10, 11 presented simulated model of a gas regulator type RPA3-50 equipped with modified spring and stress, the strain and the displacement spring.

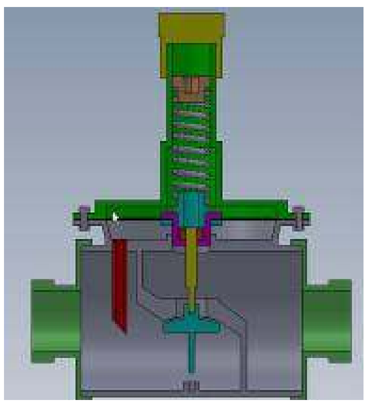

Figure 4. Normal spring

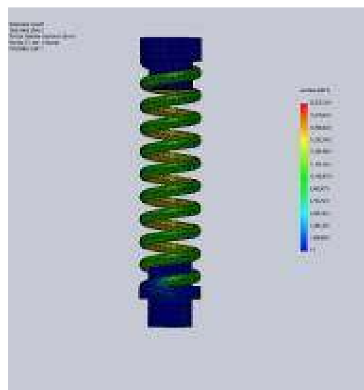

Figure 5. Result of stress

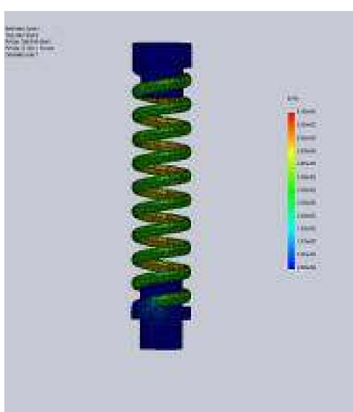

Figure 6. Result of strain

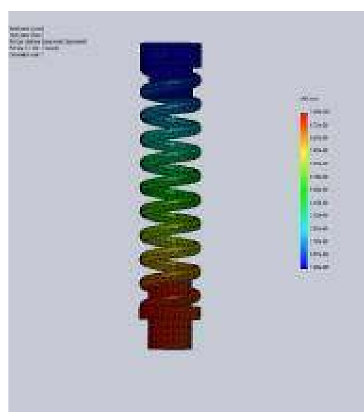

Figure 7. Result of displacement

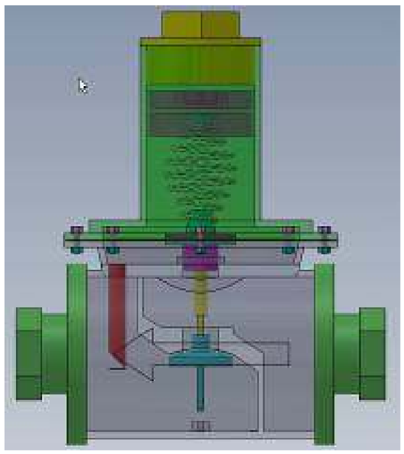

Figure 8. Modified spring

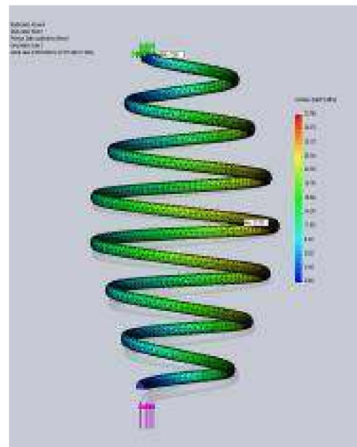

Figure 5. Result of stress

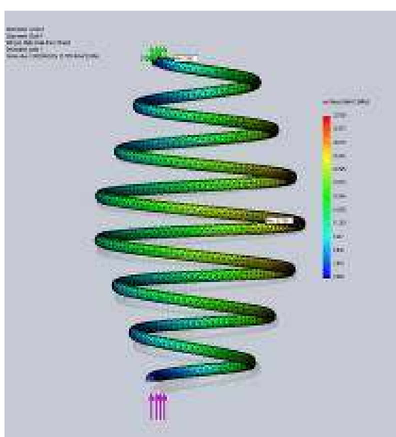

Figure 10. Result of strain

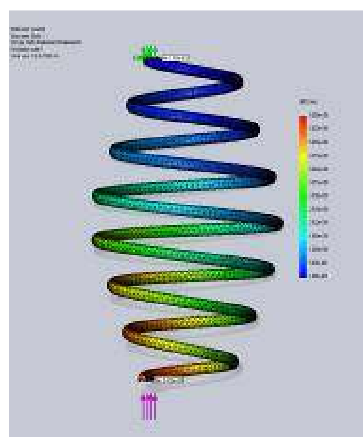

Figure 11. Result of displacement

3. Conclusion

Optimizing operation of pressure regulators for natural gas by proper sizing of coil springs, the composition, leads to reduced time constants. Using CAD and CAE techniques and finite element method brings a number of advantages over traditional methods used in design and size of gas pressure regulators:

- Design is much faster using electronic computers;
- Dimensioning is faster and more accurate, based on experimental data and using the law of similarity and extrapolation can save time and materials for new products;
- Achieve rapid 2D and 3D models and drawings needed to manufacture phase;
- The possibility of applying the continuation of CAD and CAE techniques, the art CAM (Computer Aided Manufacturing), to achieve phase manufacturing CNC machine tools.

Future studies will focus on research, the optimization of gas regulators by altering the shape of the membrane structural order and the use of modern materials in its construction.

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