CONTROL VALVES TRIM DESIGN, RETROFITTING AND TESTING

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Abstract: Control valves have numerous applications like in natural gas control and transport (as anti surge and recycle valves, hot/cold bypass valves, throttling valves, degasser flow/level control valves), natural gas treatment for dehydration and desulphuring (TEG injection, flashing drum pressure control, amine pump recirculation control valves), LNG processing (gas/steam to vent valves, blowdown and depressing valves), refineries and petrochemical (charge pump recycle valves, blowdown control valves, emergency vent valves, amine pump recycle valves), ethylene plants (feed-pump recycle valve, blowdown and gas to vent/flare valves, steam conditioning and desuperheating, compressor recycle) and etc. Valve trim is consisted of cage or dick stack, plug, stem and seat. Size from app. 15.88 mm (0.625 in) up to 101.6 mm (4 in) is suitable for 3D metal print, what is presented in this paper. Selective laser melting 3D metal printing is applied on the disc presented in this paper. Even better material properties from rest of the valve parts could be obtained. This is of great importance for valve retrofitting. In this paper is presented, also new developed channel geometry, what is followed by various fluid flow phenomena. Here is shown, in short, procedure for determination of KV-Values of the test valves according to the EN 60534-2-3, Industrial-process control valves - Part 2-3: Flow capacity - Test procedures. Some aspects of CFD calculations will be presented, also.

Keywords: control valve, trim design, standardized test procedure, 3D modeling, 3D metal and plastic printing, CFD.

1. INTRODUCTION

Control equipment is widely used, not only in technical systems. One of the most successful technology proven on the field is the multi-stage and multi path technology. It utilizes turns in the flow channels of various geometries (mostly used are 90° angle turns) with the aim to reduce the fluid's energy. Constant design and production modifications of the existing trim design are ongoing [1, 2]. Main components of the control valve are presented in Figure 1.

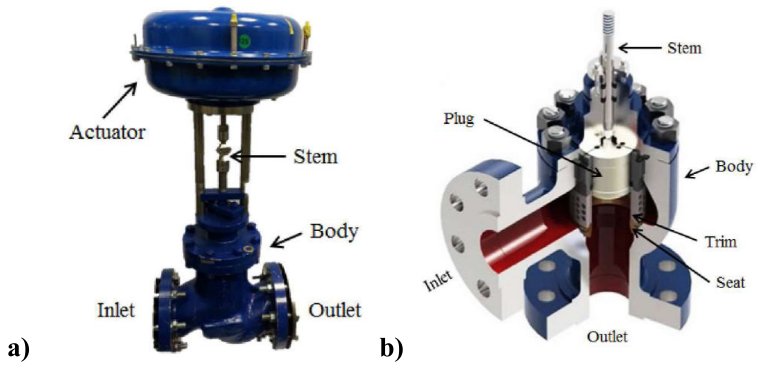

Figure 1: Components of the control valve a) valve with the actuator and b) valve body with the trim [1]

In this paper is discussed the trim, its design, numerical results and some aspects of testing. The modified design of a multi-stage continuous-resistance trim is presented in [1].

In [2] is discussed the sizing of the valve regulating element, according to the [3, 4], as well as some aspect of the trim manufacturing and CFD (computational fluid dynamics) results. The traditional manufacturing method has a "high risk potential for failure" [2]. "Processes like EDM (electric discharge manufacturing) for burning the flow paths into the disks, brazing (for joining the disks into a stack) and final machining of such and assemblies are not only related to very high cost, but limit also the design freedom significantly." [2]

In paper [2] and here is presented a new approach and application of additive manufacturing in materialization of the designed trim geometry. In addition, testing standard is here presented in short, as well as some comments on the obtained CFD results.

2. DESIGNED TRIMS

First approach was to develop and test the limits of the manufacturing technology by applying the SLM (selective laser melting) 3D Metal Printing process. It was used the nickel steel alloy 718. The first prototype utilised narrow channels with different geometries (1x1mm, Ø1mm; squared, circle and elliptical). These two, in combination with the mechanical properties of alloy steel used, were very challenging for this production process. However, the prototype final dimensions were Ø25.4 x Ø67 x 38 mm and flow passages utilising the multiple 90° angle turns (elliptical/ circle 12 and squared 18) were calculated and designed after the procedures presented in [3, 4]. This is presented in the paper [2]. The developed trim design is presented in Figure 2.

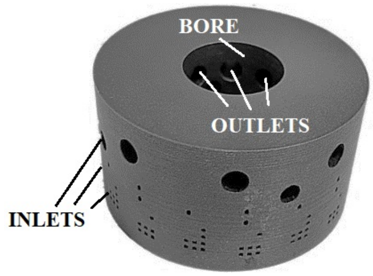

Figure 2: Manufactured first protoype by the SLM (selective laser melting) 3D Metal Printing process

In Figure 3 is presented the fluid flow filled space.

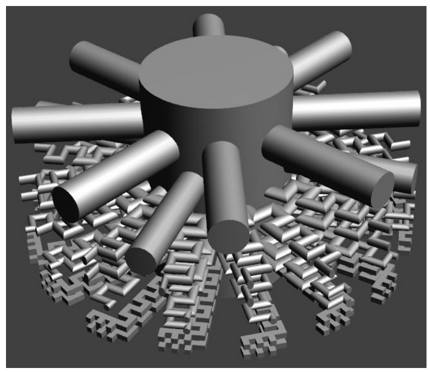

Figure 3: Trim space filled with fluid – geometry prepared for CFD

The developed and manufactured second prototype by using the 3D printinig with plastic materials (PLA, a biopolymer) is presented in Figure 4.

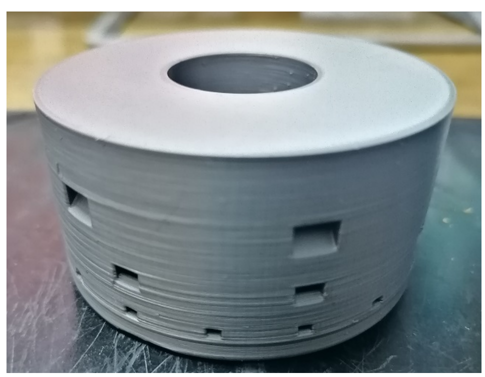

Figure 4: Manufactured second prototype by 3D printing using plastics

It has different channel geometries, also calculated after the procedures presented in [3,4]. This production procedure was, also, successfully implemented on these complex channels.

3. SOME ASPECTS TRIM TESTING AND CFD

The first trim design was tested in the Dr.-Ing. T. Bäumer GmbH, Prüflabor-Ingenieurbüro, Herford, Germany (in the following text: Test Laboratory). The tests were following the ANSI/ISA-

75.02.01-2008 (IEC 60534-2-3 Mod) “Control Valve Capacity Test Procedures” [5], i.e. DIN EN 60534-2-3. “Industrial-process control valves – Part 2-3: Flow capacity - Test procedures (IEC 65B/865/CD:2013).” [6], with the support of the company VLL solutions, Vienna, Austria.

A basic flow test system is presented in Figure 5.

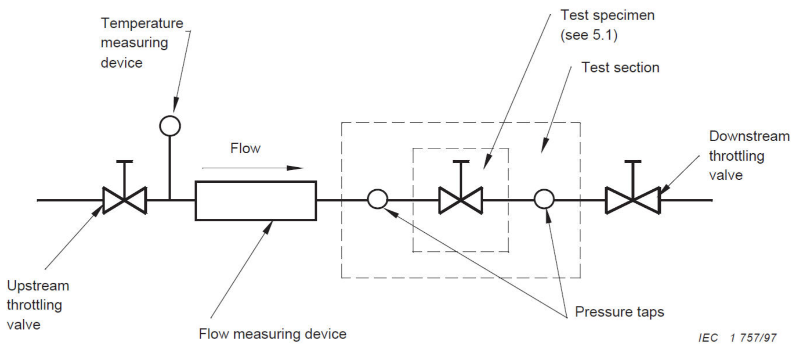

Figure 5: Basic flow test system after the [6]

“The test specimen is any valve or combination of valve, pipe reducer, and expander or other devices attached to the valve body for which test data are required.” [6]. In the case when the first trim design was tested, the flow test system presented in Figure 6. was used, where Control valve is the throttling valve, FIR is the flow measurement device, TIR is temperature measurement, while PIR are pressure measurement devices. Test valve is the tested trim design.

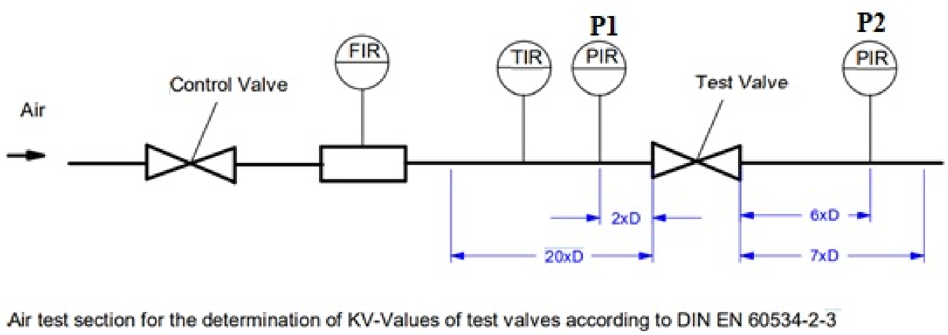

Figure 6: Air test section for the determination of KV-values of test valves according to [6]

Air was used for valve testing and it was incompressible case. Trim was positioned in the cylindrical box, i.e. in valve gallery, and its top was blocked. It was tested with the fully open inlets, and closed the first and the second row (Figure 2). Some confusing hydraulic results are obtained and answers from the Test Laboratory are still awaited.
However, these tests have proven that first trim design specimen survived tests.

These tests, according to the [6], are also planned for the second trim design, but they will be performed in the Laboratory for hydraulic machinery and energy systems Faculty of Mechanical Engineering University of Belgrade.
Some CFD calculations have been performed on the first trim design (Figures 2 and 3). Water was considered as the working fluid. Ustructured mesh with 5.8 mil. elements was used (Figure 7). Twenty layers within boundary layer were considered.

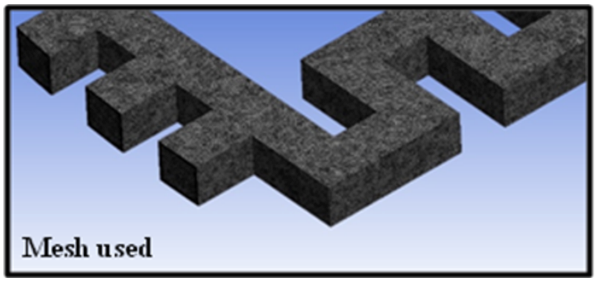

Figure 7: Unstructure mesh for CFD calculations on the first trim design

Designed regulative element, i.e. the first trim design has various levels of openness. In Figure 8. is presented pressure distribution for the lowest flow rate. In this case, only the lowest level of channels is open. Proved experimental results were not obtained, so this couldn't be tested.

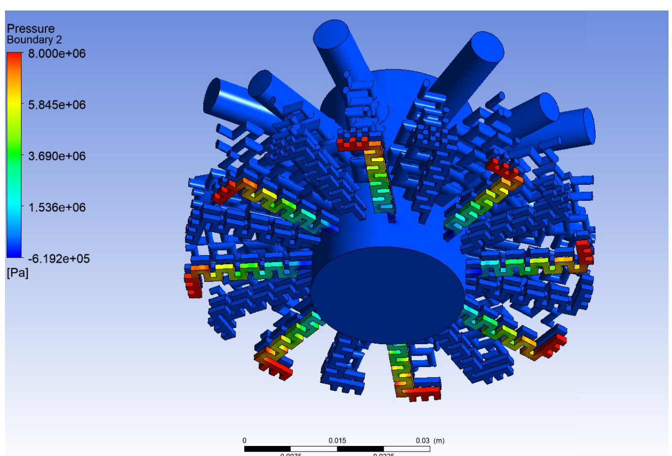

Figure 8: Pressure distribution for the lowest flow rate

Designed first trim geometry has eight channels with three inlets each and they have the same outlet. It is planned, also, to test this geometry within valve gallery. Boundary conditions are here defined on the channels' inlets, while outlet at the exit of the cylindrical chamber.
Velocity distribution for the same case is presented in the Figure 9.

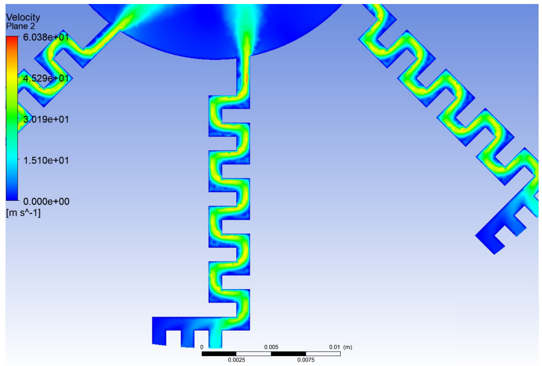

Figure 9: Velocity distribution for the first trim design

Dead flow zones are obvious in the channels corners. Turbulence kinetic energy distribution in trim geometry for the lowest flow rate is presented in the Figure 10.

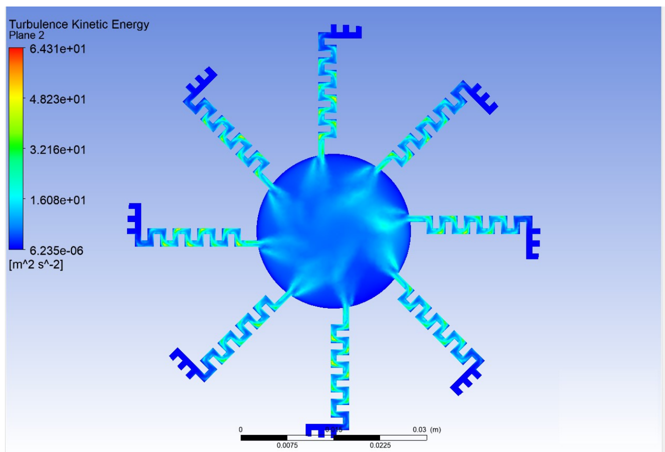

Figure 10: Turbulence kinetic energy for the first trim design

These results are presented with the aim to show turbulence character in theses trim patterns.

4. CONCLUSIONS

Two trim designs are developed and presented in this paper. The first regulative element geometry is manufactured by selective laser melting by using the alloy 718, while the second one with the additive manufacturing by using the printer and plastic materials. Channels of various sizes and geometries were used and they were properly manufactured in both cases.

Some experiments are performed, but some are in progress. Obtained experimental results will be implemented as the boundary conditions for the further numerical simulations. In this way the energy dissipation process will be thoroughly analyzed.

So, it could be concluded the following:

- SLM 3D metal print, by using the Alloy 718, is well suited as manufacturing method of regulative element,
- Elliptical, squared and round flow channels are successfully utilized within the regulative elements, i.e. in both trim geometries,
- CFD calculation for the first trim geometry gave the first approach in the study of the turbulence flow inside the trim geometry, whis is correkated with the energy dissipation processes in these regulating elements.

ACKNOWLEDGEMENT

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