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# THE INFLUENCE OF THE NUMBER OF FINITE VOLUMES AND MESH REFINEMENT ON Δp - Q CHARACTERISTICS IN THE ANALYSIS OF HYDRAULIC OIL FLOW THROUGH THE CHAMBERS AND CHANNELS OF CYLINDRICAL PISTON DISTRIBUTING VALVE

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**SUMMARY**
*The developments in Computational Fluid Dynamics (CFD) during the last decade have enabled accurate and reliable calculation of velocity, pressure and temperature fields in fluid flow through different mechanical parts and systems. The quality of results numerically obtained depends on the quality of finite volume mesh, i.e. the number and type of finite volumes that are used in mesh generation. The numerical analysis of stationary oil flow through chambers and channels of cylindrical piston distributing valve was performed and this paper presents the influence of the number of finite volumes and mesh refinement on Δp - Q characteristics of the valve.*
**Key words**: numerical mesh, number of finite volumes, numerical mesh refinement

## 1. INTRODUCTION

Cylindrical piston distributing valve is one of the most important control and regulating components of hydraulic systems. In classic hydraulics the main function of distributing valves is to control the flow of fluids. Additionally, in proportional and servo hydraulics distributing valves have a great influence on kinematic, dynamic and fluid pressure characteristics.

The use of hydraulic fluid systems with classical, proportional and servo distributing valves is very common and important in industrial applications. Consequently, number of engineering and scientific investigations deal with the analysis of distributing valves, [1]. However, Computer Fluid Dynamics (CFD), i.e. numerical analysis of fluid flow through channels and chambers of cylindrical piston distributing valves and their operating performances has been used only in a few special cases. The analyses were performed on simple two-dimensional models using some of the special programs developed for simulations.

For instance, A.Kilchmann used the finite difference method in his investigations. On the basis of R.N.Clark investigations, M.Y.Guo and K.Nakano used the boundary elements method to analyze the compensation of fluid force acting on a valve piston. Also, T.Tsukiji used numerical analysis in investigation and simulation of the fluid flow by discrete vortex method.

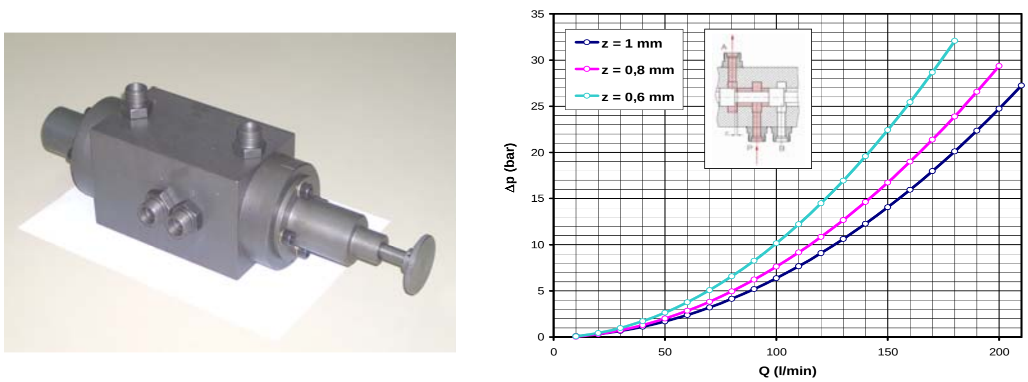
In recent years many authors have used numerical methods such as Finite Element Method (FEM) and Finite Volume Method (FVM) to analyze the fluid flow in cylindrical piston distributing valves. Some of those who used FEM are: M. Kipping, Th. Grauer , H.-Th. Nguyen , C. Jansson , K. Engelsdorf, K. Klarecky, E. Tomasiak and J. Kosmol. The use of FVM can be found in investigations of X. Baudrya, J.-C. Marea and M. Ristić.

## 2. NUMERICAL ANALYSIS, RESULTS AND DISCUSSION

### 2.1 Introduction

The quality of the results obtained by numerical analysis of fluid flow greatly depends on numerical mesh definition, i.e. the number and the type of finite volumes used in mesh generation. This paper presents some of the results related to the influence of the number of finite volumes and the mesh refinement in characteristic zones of chambers and channels of cylindrical piston distributing valve on *Δp - Q* characteristics. The results refer to the stationary hydraulic oil flow from opening P to the A for three cases of gap dimension, Figure 1.

The analysis was performed on the model of cylindrical piston distributing valve shown on Fig.1.a. Figure 1.b presents the experimentally obtained *Δp - Q* characteristics of the model for three values of the gap: z = 1,0 mm, z = 0,8 mm i z = 0,6 mm, [1,2].




*a) Cylindrical piston distributing valve*

*b) Experimentally obtained Δp - Q characteristics for three values of gap dimension*

*Figure 1. Model of cylindrical piston distributing valve used for the analysis, and experimentally obtained Δp - Q characteristics for the model*

The numerical analysis of hydraulic oil stationary flow through chambers and channels of cylindrical piston distributing valve was performed using the software *Comet,* which is based on Finite Volume Method (FVM), [3].

### 2.2 Results and discussion

The analysis of the influence of the number of finite volumes and mesh refinement on *Δp - Q* characteristics in case of hydraulic oil stationary flow through chambers and channels of cylindrical piston distributing valve from opening P to the point A and gap dimension of z = 1,0 mm was performed using several numerical meshes. Some of them are shown on Figures 2.

Figure 3 presents the numerical results for *Δp – Q* characteristics obtained by different numerical meshes and the corresponding experimental data as well. The results of numerical and experimental data show high level of agreement. One can see that more accurate results are obtained by higher number of finite volumes and better mesh refinement. Also, the same refers to the other two values of gap dimension, i.e. z = 0,8 mm and z = 0,6 mm, and other directions of hydraulic oil flow as well.

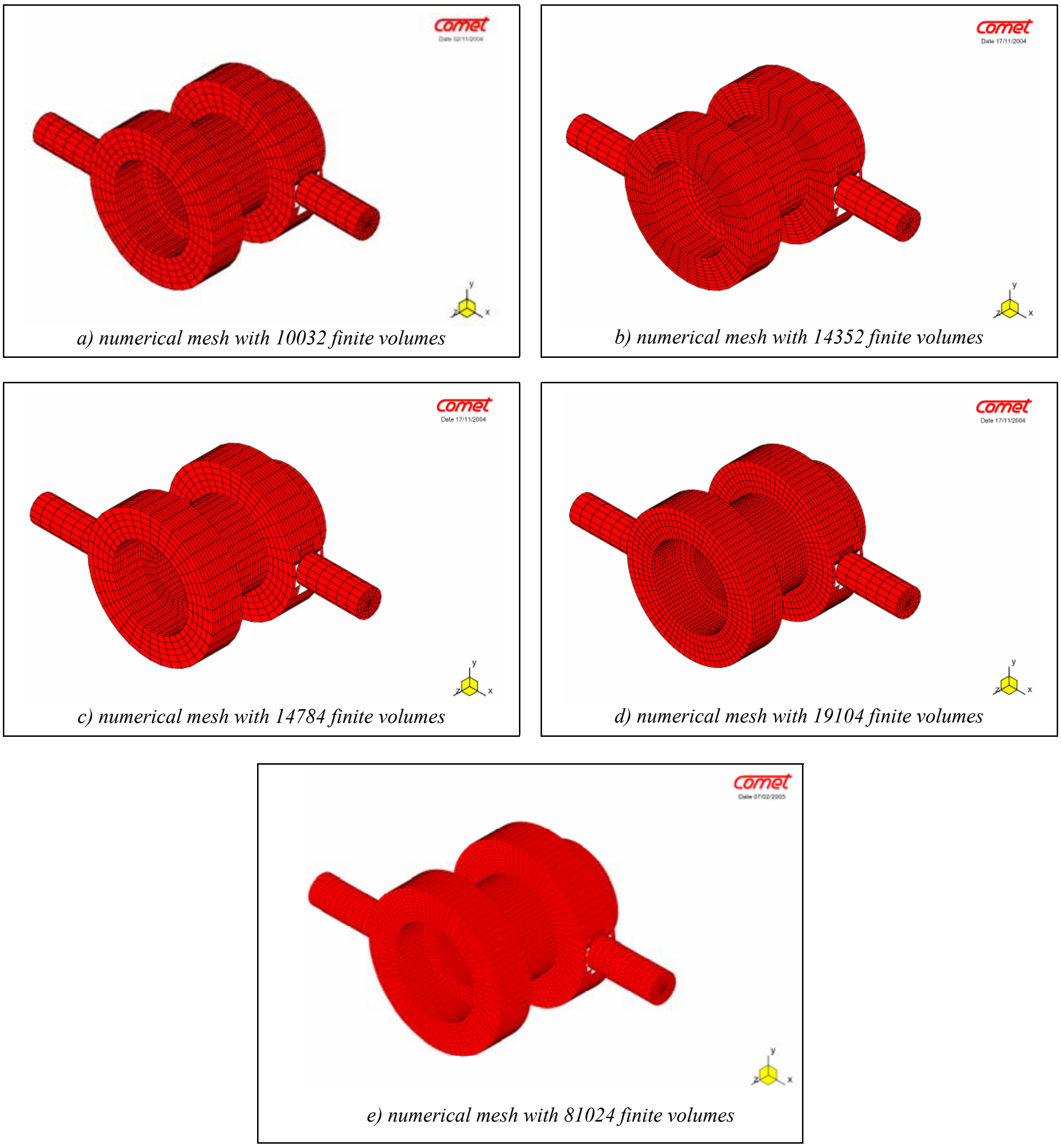



*Figure 2. Numerical meshes used in the analysis, gap dimension z = 1,0 mm*

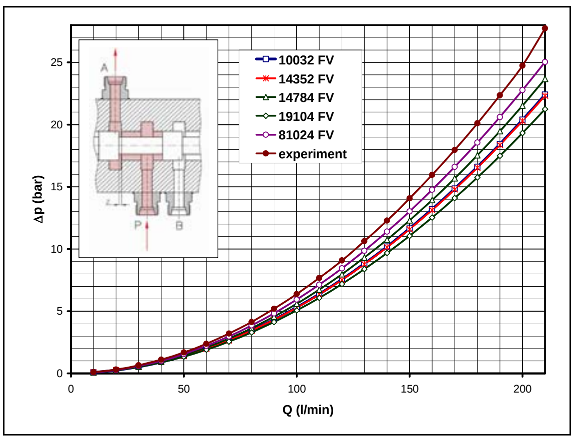



*Figure 3. Experimentally and numerically obtained Δp - Q characteristics for different numerical meshes*

For instance, the pressure drop values *Δp* obtained by numerical mesh presented on Figure 2.a differ slightly from the values obtained by numerical meshes on Figure 2.b (in average 0,38 %) and Figure 2.d (in average 4,47 %), although the difference in finite volumes number is more pronounced ( 4320 volumes or approx. 43,1 % in the first case, and 9072 volumes or approx. 90,43 % in the second). The numerical meshes shown on Figures 2.b and 2.d differ from the numerical mesh 2.a in a fine refinement of the input and output chamber (and also the central channel in case 2.d).

Also, a slight difference in drop pressure values *Δp* can be found comparing the results of numerical mesh 2.a and numerical mesh 2.c (in average -4,47 %). In numerical mesh 2.c, the refinement of the central channel was done which was not the case in numerical mesh 2.a.

Numerical mesh shown on Figure 2.e consists of eight times higher number of finite volumes in comparison to the numerical mesh 2.a due to fine refinement of the mesh performed in all channels and chambers. The difference in the pressure drop value *Δp* is approximately 10 %.

## 3. CONCLUSION

Generally, numerical analysis never provides absolutely accurate results. However, systematic refinement of the numerical mesh gives an opportunity to obtain the value of characteristic variable closer to the real one. In this analysis, the experimentally obtained values of *Δp - Q* characteristics are assumed to be accurate. The analytical results are also approximate due to presumptions of the underlying theory. Numerical mesh shown on Figure 2.e gave the results for pressure drop *Δp* which differ 6 % in average from experimental, which seems acceptable for this kind of problems. Higher level of refinement, which was used in cases with gap dimensions of z = 0,8 mm i z = 0,6 mm also gave the difference of less than 6 % between numerical and experimental values. On a certain level of mesh refinement no improvement in results appears, which means that further refinement has no sense. It seems reasonable to adopt those limits of accuracy that are appropriate for engineering practice and have no practical influence on the real process analysis.

An important fact that should be emphasized here is that numerical mesh refinement could be done in both local and global level. Local refinement should be performed in those locations where greater changes of the characteristic variable could be expected. This provides more detailed and better analysis of the characteristic variable and its influence on the process. The importance of the local refinement is proved by this analysis. For instance, different local refinement in numerical meshes shown on Figures 2.b and 2.c gave the difference of *Δp* values of approximately 5% although almost the same number of finite volumes was used.

Further analysis has also shown that higher number of finite volumes requires more iterations and prolonged time for calculation. Numerical meshes shown on Figures 2.a, 2.b, 2.d and 2.e mostly requires more iterations and time when flow rate or flow velocity increase. In case of numerical mesh on Figure 2.c, the number of iterations and calculation time alternate with flow rate and velocity. The duration of time necessary to calculate the pressure drop in hydraulic oil stationary flow from point P to A varies in range of 0.32 - 3.07 hours, depending on the flow rate *Q* and gap dimensions *z*. More iterations and, consequently, longer computing time are required in cases of higher number of finite volumes, higher flow rate *Q* and lower gap dimension *z*.

## 4. REFERENCES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