STRESS-STRAIN ANALYSIS AT HYDRO ACCUMULATOR CYLINDER

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Abstract. The analysis of the stress – strain at hydro accumulator cylinder under the various load conditions by experimental and numerical method are presented in this paper. The considered hydro accumulator is used at hydraulic installation of air plane. For experimental testing, extension measuring methods by strain gauges are used. Testing device that allows variations of load pressures within hydro accumulator cylinder is used. For temperature measurement, the thermocouple copper-constantan connected to miliampermeter graduate for different values of temperatures in Celsius scale is used. The numerical simulation of stress-strain state under different values of load pressure is done. The correlations of related results obtained by experimental testing and numerical simulation are done. The values obtained by measuring and related ones, that are numerically calculated are presented by diagrams of stresses and deformations in functions of load pressures. The research presented in this paper highlight hydro accumulator cylinder answer to different load pressures under exploitation conditions, so to define real limits of load pressure during exploitation. The fully understanding of stress-strain state at hydro accumulator cylinder in exploitation is key element of safety and reliability analysis of air plane hydraulic installation.

1. Introduction

Hydro accumulators are devices that obtained accumulation of potential energy of active fluid. Basic function of hydro accumulator is to accumulate hydraulic energy when hydro aggregates (users) in system do not use this energy and to supply those users when they are active. Hydro accumulators at hydraulic installations could do various functions of accumulation and circulation of energy. Experimental and numerical analysis of stress-strain state at hydro accumulator that belongs to the piston type hydro accumulators used at hydraulic installation of air plane are presented in this paper. Considered hydro accumulator provides reserve of pressured fluid that with flow of the pump provide absorption of current maximums of fluid usages at devices. Also, it provides easy functioning of hydraulic installation by absorbing pressure variations. The aim of this paper is to identify optimal form and dimensions by experimental and numerical analysis as function of load changing with consideration of geometrical shape and stress concentration.
To the aim of stress-strain analysis is considered vibration analysis of a hydraulic cylinder subjected to dynamic load [1]. Also is done stress and strain investigation at hydro

accumulator cylinder with various load conditions by the strain gauge [2]. The present results of strength and fatigue limits analysis applied to piston type hydraulic cylinder [3] are used in consideration of this problem. This paper also shows advantages of application of the up-to-date digital chain of engineering analysis within which CAD tools are being used as well as strength and fatigue limit analysis.

2. Stress-strain analysis at hydro accumulator cylinder

2.1. Hydro accumulator cylinder

Cylinders are mainly made of steel forgings and tubes, rarely of cast iron and, sometimes, aluminum alloys are used [4]. Due to improve hardens of inner active surface, electrolytic chromatins is done with layer thickness of 0.2 mm.
The examined hydro accumulator cylinder is made of Č.5432 according to Serbian National Standard, relate 18CrNi8 according to German National Standard DIN with working fluid hydraulic oil AMG 10 that fulfill National Russian Federation Standard GOST 6794-75 effective pressure of 206 bar, maximum capacity of 1800 cm^3, maximum gas capacity of 2000 cm^3 and nominal diameter of the piston 100 mm with ARS Aero connection. Model of considered hydro accumulator cylinder is presented at Fig. 1.

Figure 1. Model of hydro accumulator cylinder

During production, hydro accumulator cylinders are subjected to strict testings according to related standards under different exploitation conditions – working pressure.

2.2. Stress-strain analysis at hydro accumulator cylinder by experimental method

In laboratory conditions stress and deformation values were measured using strain gauges under different values of effective pressure. Also, degree of widening of the hydro accumulator cylinder at specific zones under different pressures was measured. Universal testing installation, part of the cylinder with strain gauges, plotter and signal amplifier are presented at Fig. 2. Schematic representation of the testing device is presented at Fig. 3. The testing is done at hydro accumulator cylinder without piston that made the process simpler but the authenticities of tests were not lessened. Positions of the measuring and compensation strain gauges on considered hydro accumulator cylinder are presented at Fig. 4.

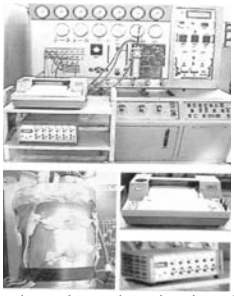

Figure 2. The universal testing installation [2]

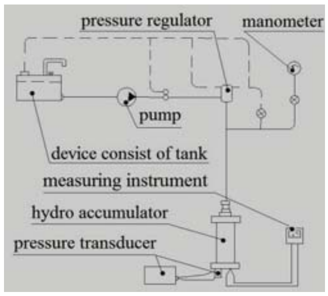

Figure 3. Scheme of the testing device [2]

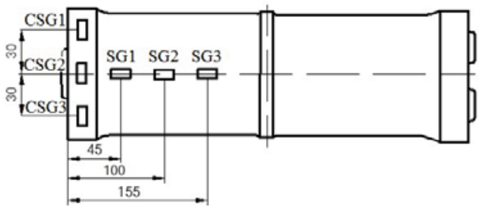

Figure 4. Positions of measuring and compensatory strain gauges at cylinder
(SG – strain gauge, CSG - compensation strain gauge) [2]

On the basic of the measured values of deformations, diagrams of relative deformation ε[μm/m] dependence of pressure p[bar] for the longitudinal and transverse axis are formed (Fig. 5 and Fig. 6). The stress σ[MPa] dependence of pressure p[bar] for the longitudinal and transverse axis of the cylinder are shown at Fig. 7 and Fig. 8.

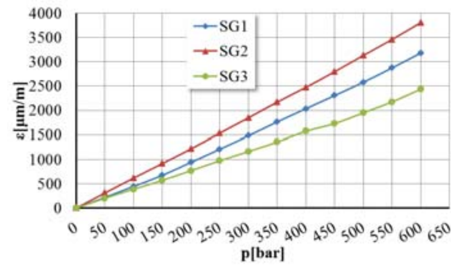

Figure 5. Diagrams of relative deformations ε[μm/m] dependence of pressures p[bar] for the longitudinal axis of cylinder

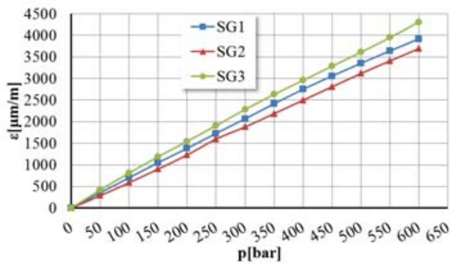

Figure 6. Diagram of relative deformations ε[μm/m] dependence of pressures p[bar] for the transverse axis of cylinder

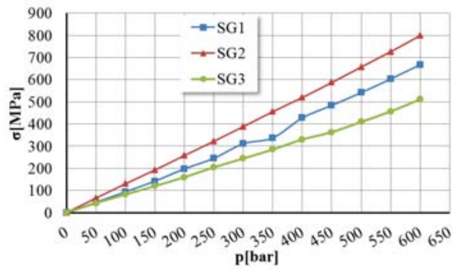

Figure 7. Diagrams of stresses σ[MPa] dependence of pressures p[bar] for the longitudinal axis of cylinder

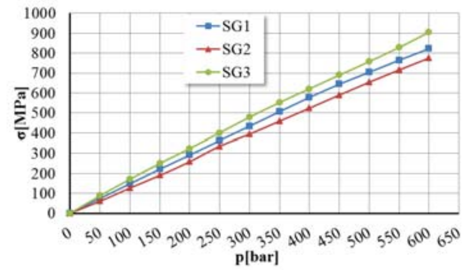

Figure 8. Diagrams of stresses σ[MPa] dependence of pressures p[bar] for the transverse axis of cylinder

On the basis of the measured values it can be concluded that the maximum stresses obtained for direction of longitudinal axis σ_{umax}=799.3 MPa is lower than tensile strength R_m=1100–1300 MPa and yield strength R_{eh}=900 MPa of the cylinder material. It is implicated that under pressures of 600 bar and more, permanent deformations of the hydro accumulator cylinder can occur.

2.3. Stress analysis at hydro accumulator cylinder by numerical method

In the aim to identify the optimal constructive solution, dimensions and form of considered hydro accumulator cylinder, numeric analyze of stress state was done by finite element method. The most of the numeric methods for calculation of stress at mechanical constructions are based on the finite element method [6]. Geometric Computer Aided Design (CAD) model of hydro accumulator cylinder is formed from simple geometrical shapes called geometric forms. Load simulation at hydro accumulator cylinder barrel is done by using of software *Autodesk Inventor Professional 2013* and it is presented in this paper [7]. The basic model that is used for numeric analysis is related to considered hydro cylinder. For material properties, the module of elasticity and Poisson ration are used as $E=2.1\cdot10^5$ MPa and μ=0.3. At first stage of generation of the numerical model, discretization is done by 3D tetrahedral finite elements. Special consideration was put at cylindrical active surface where pressure act, so this part was discretized by finite elements with smallest dimensions (Fig. 9). The border conditions are defined in relations to theoretic considerations of hydro cylinder. The numeric calculations are done, firstly, at simplified model and after that, numeric analyze of stress state due to different internal pressure is done.

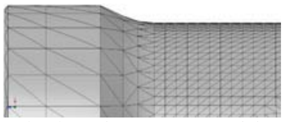

Figure 9. Discretization of one segment of the numeric model

3. Results of numeric analysis

In order to numeric calculation has been done, it is necessary to repeat the procedure of structural analysis for every value of pressure. The every analysis is done for different values of pressure within interval between 50 bar and 400 bar with step of 50 bar and for value of p=600 bar. As results of numeric analyze stresses at transversal directions are obtained. Visualizations of results of calculations of stresses for extreme values of pressure are presented at Fig.10 and Fig.11.

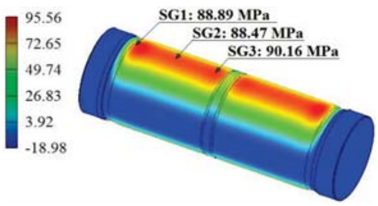

Figure 10. Stresses in transversal direction at hydro accumulator cylinder due to pressure p=50 bar

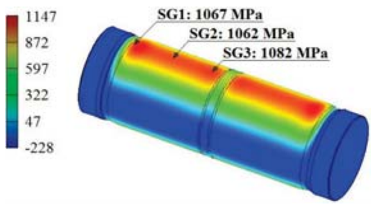

Figure 11. Stresses in transversal direction at hydro accumulator cylinder due to pressure p=600 bar

4. Evaluation of results

Evaluations of the results provide precise determinations of stress state at positions of strain gauges at considered hydro accumulator cylinder. Comparison of results obtained by experimental and numeric methods are presented at Fig. 12, Fig. 13 and Fig 14.

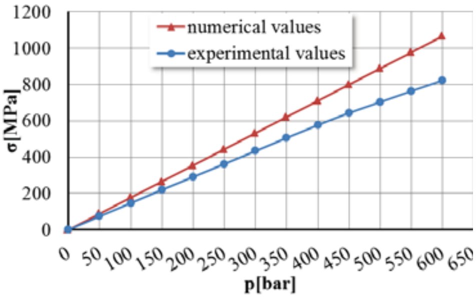

Figure 12. Stress analysis at hydro accumulator cylinder barrel at position SG1

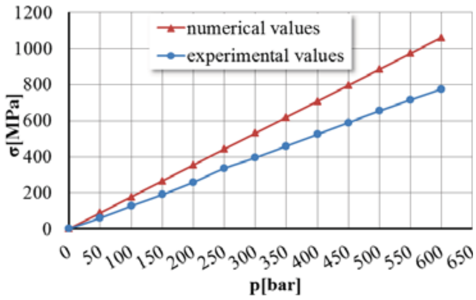

Figure 13. Stress analysis at hydro accumulator cylinder barrel at position SG2

Maximum value of stress obtained by numerical analysis due to simplification of numerical model (stress concentration at the zone of shape transition from inactive part to the cylinder) that is not taken into account in calculation of stresses at the positions of strain gauges.

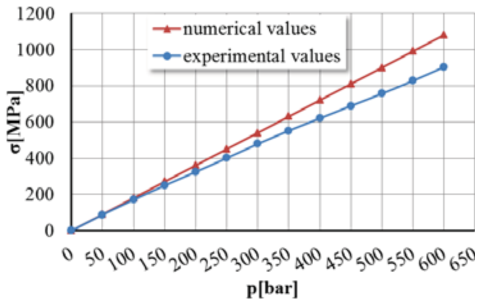

Figure 14. Stress analysis at hydro accumulator cylinder barrel at position SG3

Linear increases of stresses calculated by numeric method in relation to related values obtained by experimental method provide precise calculation of stresses state point out the zones with high stress concentrations, shown at Fig. 13. Those stress influent safety and reliability, so as to reduction of exploitation period of cylinder. Stress concentration at those zones present one of the major causes of failures at hydro accumulator cylinders.

5. Conclusion

The experimental examination which was carried out gives significant indications and general information about the behavior of hydro accumulators during exploitation. These analyses identified exploitative conditions at which it is possible to expect irregularities during functioning of hydro accumulators.

On the basis of the conducted evaluation of obtained results, following general conclusions are implicated:

- Diagrams of stresses obtained by experimental method point out that value of stresses at considered points, so as identification of failure position at considered model by numeric method is relevant and relate to adequate construction solution. The mathematical model that is formed can be taken for further analysis and testing in aim to obtain decrease of maximal stress level.
- Values of stresses calculated by numeric method are higher than related values calculated by experimental method due to fact stress concentration.

On the basis of those conclusions it is implicated that both experimental and numeric methods provide relevant results due to sensitivities to alterations of input parameters, but special care should be taken to influence of stress concentration at zones of the cylinders. The alterations of maximal result stresses at specific zones of hydraulic cylinder are highly influenced by alterations of maximal pressure inside of cylinder. Conducted analyses provide precise identification of optimal construction solution, so as identification of its optimal form and by that, provide prevention of damages and failures at maximal pressures during exploitation.

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