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Book of Abstracts

power is specified. A device which contains a piezoelectric element is used for vibration energy harvesting. The interaction between mechanic and electric part of the system is taken into consideration. Two types of piezoelectric elements are analyzed: linear and nonlinear. Motion is described with a system of two coupled equations. In the paper the equations are solved numerically. Advantages and disadvantages of the ambient vibration energy harvester with piezoelectric element are presented. The direction for future investigation to eliminate the lack of the harvester is suggested.

M.2.3 - *Lifetime Prediction of Cardiovascular Stent Based on Fatigue to Fracture Approach* - Gordana Jovičić, Arso Vukicević, Dalibor Nikolić, Nenad Filipović

The principal aim of this study was to define and apply numerical procedures to assess the durability of coronary stents based on the estimation of safety from fatigue to fracture. This procedure is carried out within three phases: a) initial fatigue analysis based on S-N approach; b) fatigue lifetime assessment based on fatigue crack growth simulation using Paris-power law, and c) safe-operation i.e., no-fatigue failure (based on forming of Kitagawa-Takahashi diagram) as well as immediate fracture event predictions of the stent. The results indicated that the presented numerical algorithm gave an estimation of structural survival/durability on the side of safety that can be combined efficiently with other experimental procedures during the phase of stent design.

M.2.4 - *Analysis of Loads and Deformation of Valve Plate in Contact with Cylinder Block at Axial Piston Pump for Water Hydraulics* - Nenad Todić, Snežana Vulović, Miroslav Živković, Slobodan Savić, Vesna Ranković

This paper focuses on mathematical modeling of axial piston pump for water hydrailucs. The cylinder block-valve plate plays an important role in the axial piston pump because its failures predominate in maintenance. Through analyzing the surface morphology of the worn valve plate, its eccentric wear in the high-pressure area occupies the primary position. Since the axial piston pump is full of fluid, its normal operation depends on the lubrication between the friction pairs. Based on the tribology theory, most of abrasive wear of the axial piston pump is caused by fluid damage between the friction pair surfaces. Under ideal condition, there is a layer of fluid between the valve plate and the cylinder block, which lubricates the operation of the friction pair. Tribological problems with the axial piston pumps for water hydraulics are particularly pronounced because of temperature load and wear. This paper analyzes the load of the contact block and the plate in the phases of suction and pressure and interaction between the fluid and the contact surface of the plate.

Session M.3 - 13:10-14:00
Data Mining

Chair: Bojana Anđelković Ćirković

M.3.1 - *Automatic Main Pulmonary Artery Identification on Chest CT using Supervised Machine Learning* - Daniel A. Moses, Laughlin Dawes, Claude Sammut, Tatjana Zrimec

The pulmonary arterial system can be affected by many pathological processes with potentially lethal consequences. Automatic detection and extraction of the pulmonary arteries can significantly speed up the diagnosis and intervention. In this paper we present a method for automatic seed point detection within the main pulmonary artery (MPA) in CT data to aid its segmentation. We used supervised machine learning to train models that can accurately predict images that contain the MPA in 3 orthogonal anatomical planes: axial, coronal and sagittal. Through intersection of these predicted images we triangulate the likely position of the seed point in the MPA on each of the 3D data sets. Experiments were performed on CT datasets from fifty patients and with different machine learning algorithms: ANN, SVM, naïve Bayes and kNN. The best performance for accurate main pulmonary artery localization (92%) was seen at the models tarnished with the SVM with Radial Basis Function kernel.

M.3.2 - *Framework for creation of customized shape of the shoe insole* - Suzana Petrović Savić, Zoran Jovanović, Goran Devedžić

Foot is the body part which is in constant contact with the ground. Since foot has to adjust to the ground and transfer body weight properly, it is very susceptible to injuries and deformities. One of the most common deformities is flat foot that implies fallen arches. These deformities influence non-amenity during walking and irregular body weight transfer. In order to return foot mechanics in normal acting, it is necessary to wear corrective insoles. This study presents methodology aiming at speeding up the customized insole manufacturing process through creation of so-called "digital chain". Patients with flat foot leave footprint in polyurethane foam, which is later scanned and transferred into digital model. Selecting the appropriate points of the acquired scanned image data set defines input parameters for creating spatial insole shape. These parameters, consequently, define boundary spatial curves, which in turn rule the insole's free form shape. This is the basis for upgrading and setting up the initial shape with corrective elements.

M.3.3 - *Multiscale Microstructural Optimization of Carbon Nanotube/Polymer Structures using Genetic Algorithms* - Maria Tavlaki, Odysseas Kokkinos, Vissarion Papadopoulos, Manolis Papadrakakis

Analysis of Loads and Deformation of Valve Plate in Contact with Cylinder Block at Axial Piston Pump for Water Hydraulics

Nenad Todić[1], Snežana Vulović[1], Miroslav Živković[1], Slobodan Savić[1], Vesna Ranković[1]

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Abstract

This paper focuses on mathematical modeling of axial piston pump for water hydrailucs. The cylinder block-valve plate plays an important role in the axial piston pump because its failures predominate in maintenance. Through analyzing the surface morphology of the worn valve plate, its eccentric wear in the high pressure area occupies the primary position. Since the axial piston pump is full of fluid, its normal operation depends on the lubrication between the friction pairs. Based on the tribology theory, most of abrasive wear of the axial piston pump is caused by fluid damage between the friction pair surfaces. Under ideal condition, there is a layer of fluid between the valve plate and the cylinder block, which lubricates the operation of the friction pair. Tribological problems with the axial piston pumps for water hydraulics are particularly pronounced because of temperature load and wear. This paper gives analysis of the load of the contact block and the plate in the phases of suction and pressure and interaction between the fluid and the contact surface of the plate.

Keywords: axial piston pump, water hydraulics, valve plate, cylinder block, friction pairs

1. Introduction

There are two types of analysis of the axial piston: one focuses on the lubrication and another emphasizes wear and tear (Shaoping, Tomovic and Lei, 2017). In 1986, Yagaguchi studied the lubrication between the valve plate and cylinder block, and gave the mathematical model of fluid (Yamaguchi, 1986). Based on this model, he established the dynamic model of the cylinder block, calculated its force and torque, and provided the stable condition of constant fluid between the valve plate and the cylinder barrel (Yamaguchi, 1987).

Fig.1 shows the structure of axial piston pump, in which the valve plate and the swash plate are fixed. The shaft drives the cylinder block rotation and the pistons reciprocate in it when the axial piston pump operates. There are three friction pairs in the axial piston pump that is, cylinder block/valve plate, slipper/swash plate and piston/plunger cavity. The cylinder block-valve plate plays important role in axial piston pump because its failures predominate in maintenance (Backe, 1999).

The axial piston pump usually contains 7 or 9 pistons in the rotating cylinder block. The pistons execute linear movements into the cylinders. During one revolution the pistons execute the full stroke (Ivantysyn and Ivantysynova,2001). The pistons are connected to the swashplate with slippers, which allows rotating motion against the swashplate. The swashplate has an inclination angle which defines the stroke of the pistons (Trostmann, Frolund,Olesen and Hilbrecht, 2001). The theoretical flow of the pump is worked out with the piston area, stroke of the pistons, number of the pistons and the rotation speed of the cylinder block. The valve plate realizes the connection of the piston chambers to the suction and pressure ports. Usually, the swashplate and the valve plate are fixed and the cylinder block is the rotating part (Bergada and Kumar, 2014), (Dong, 2006.).

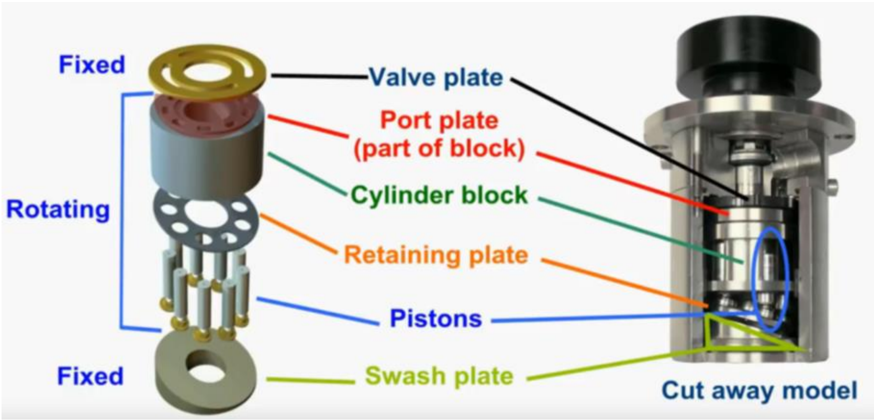

Fig. 1. Structure of axial piston pump

2. Dynamic model of cylinder block and valve plate

The relation of support force and velocity can be described with the Reynolds equation (1):

$$\frac{\partial}{\partial x}\left(\frac{\rho h^3}{\mu}\frac{\partial p_l}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\rho h^3}{\mu}\frac{\partial p_l}{\partial y}\right)=6\left[\frac{\partial}{\partial x}(v_x\rho h)+\frac{\partial}{\partial y}(v_y\rho h)+2\rho\frac{\partial h}{\partial y}\right] \qquad (1)$$

where p_l is the support force of fluid, h is fluid thickness, μ is dynamic viscosity which is related to the temperature and pressure.

The pressure distribution between cylinder block and valve plate is unbalanced, the fluid film between the friction pair is wedge-shaped, shown in Fig. 2.

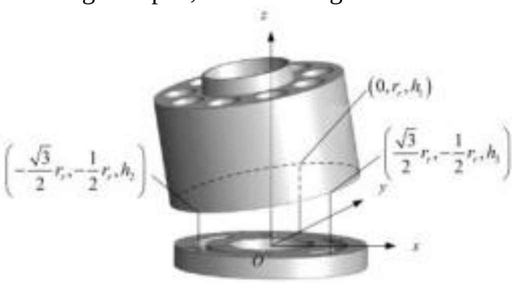

Fig.2 Fluid film between cylinder block and valve plate

For the fluid in the form of a wedge, the position of the whole cylinder block can be determined through measuring the height of 3 fixed points (Shaoping, Tomovic and Lei, 2017). Three points in cylinder block are shown in Fig.3. The fluid thickness at point can be determined with equation (2):

$$h(x,y) = \frac{h_3 - h_2}{\sqrt{3} r_r} x + \frac{2h_1 - h_2 - h_3}{3r_r} y + \frac{h_1 + h_2 + h_3}{3} \quad (2)$$

Where *x,y* is the coordinate at arbitrary point of valve plate , r_r is reference radius, h_1, h_2, h_3 are the height of oil film in distributed three points of valve plate.

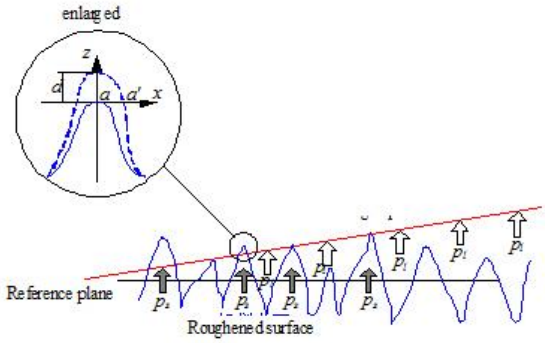

Fig. 3. Three fixed point on cylinder block

3. Materials Used for Research Valve Plate

Developments of water hydraulic axial piston machines have been made around world during the past three decades (Krutz and Chua,2004.). The research involved material research, pump design and pump tests, including life time tests. The changes in design, material selections and power pack development are discussed. The design of the pumps, material of the pumps and test results are also discussed. The combination of stainless steel and coal fibre reinforced PEEK has proven to be successful in water hydraulic pumps (Bech,Olsen and Klit,1999.). Material selection, optimizing structure and manufacturing are recognized as the key problems. Material research is an important part of water hydraulic component research. The wear mechanism of ceramic-ceramic contact is fatigue and surface fracture. In stainless steel polymer combinations, the wear mechanism of the PEEK composites is fatigue when the load is lighter, and micro-cutting and plastic deformation when the load is heavier (Rydberg,2001). The conclusion is that metal-polymer combinations are more suitable to be friction pairs in water hydraulic piston pumps, but that ceramic-ceramic combinations also have potential. Companies have some patents concerning water hydraulic axial piston pumps (Conrad,2005). Key elements of the patents are the structure and materials of the slipper. Stainless steel and industrial plastics combinations are used in all the inventions (Takashima,1996), (Koskinen,Leino and Riipinen,2008).

Material	PEEK 1	PEEK 2
Aditive	10% carbon, 10% graphite, 10% PTFE	
Young's modulus [MPa]	9500	3500
Poission ratio [-]	0.394	0.400
Density [kg/m^3]	1480	1300
Tensile strength, Yield [MPa]	119	97

Compressive yield strenth [MPa]	152	118
Friction coefficient [-]	0.19	0.34

Table 1. Material properties

4. Numerical Analysis of the Valve Plate Using the Finite Element Method (FME)

Based on the technical literature, a valve plate model was of the axial pump was developed. In computer program FEMAP (***F**inite **E**lement **M**odeling **A**nd **P**ostprocessing*) created finite element model. The valve plate is modeled using 3D tetra elements with intermediate nodes. The model consists of 307,644 nodes and 205,323 elements (Kojić, Slavković, Živković and Grujović,2010). The analysis assumed that the plate is fixed at one side Fig.5, and at the other side, the pressure is released Fig.4. On the part of the pressure distribution, the plate is loaded with a pressure of 80 bar, and the suction pressure is 1.2 bar.

In Fig.6 and Fig.7, there is the field of vertical movements, distribution boards made of a material that is PEEK1 and PEEK2, respectively. The maximum displacement of the valve plate made of material PEEK1 is 5.86 microns, the material PEEK2 is 15.8 microns. For the analyzed cases, stresses in the valve plate did not differ significantly. Distribution of equivalent stress on the valve plate is shown in Fig .8.

Based on these results it is concluded that it is better to use the material PEEK1. In further work we will study the remaining parts of the pump.

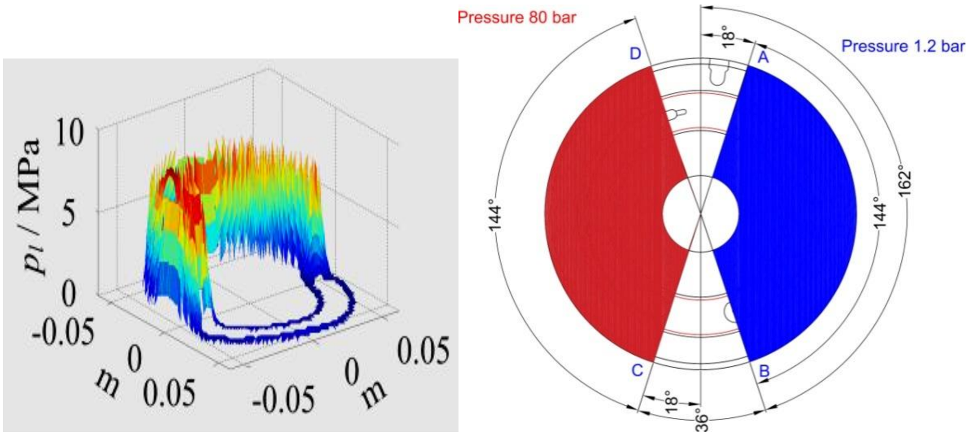

Fig. 4. Loads on the valve plate and pressure distribution [1]

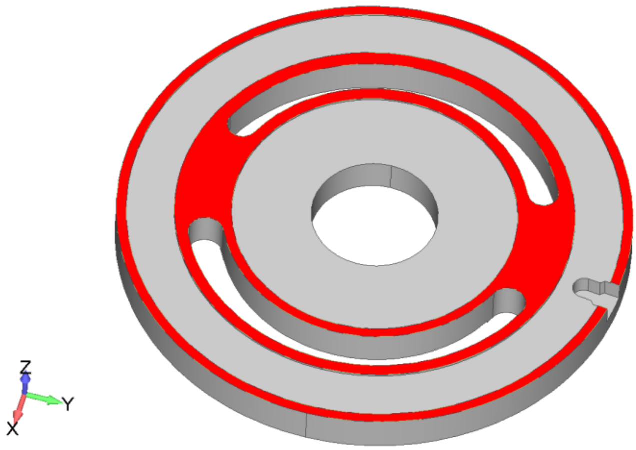

Fig 5. Surfaces to which the specified boundary condition

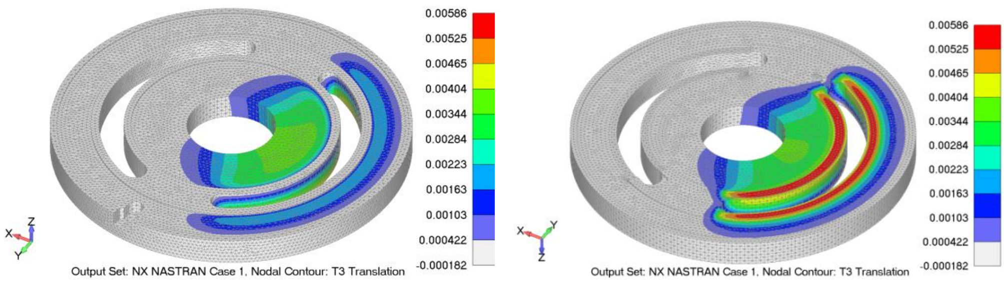

Fig. 6. Vertical displacement field, PEEK1

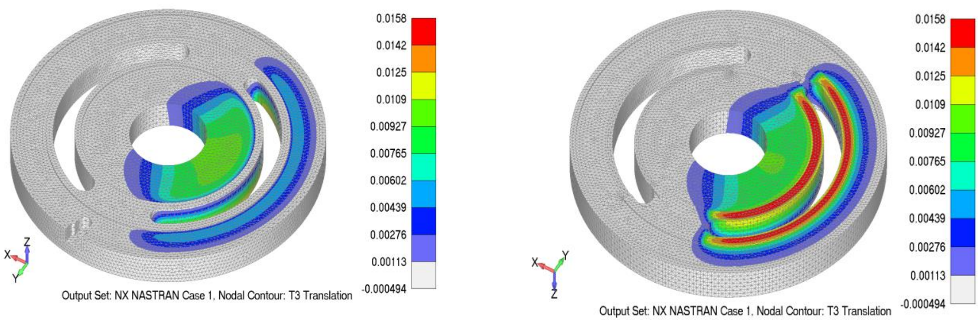

Fig. 7. Vertical displacement field PEEK2

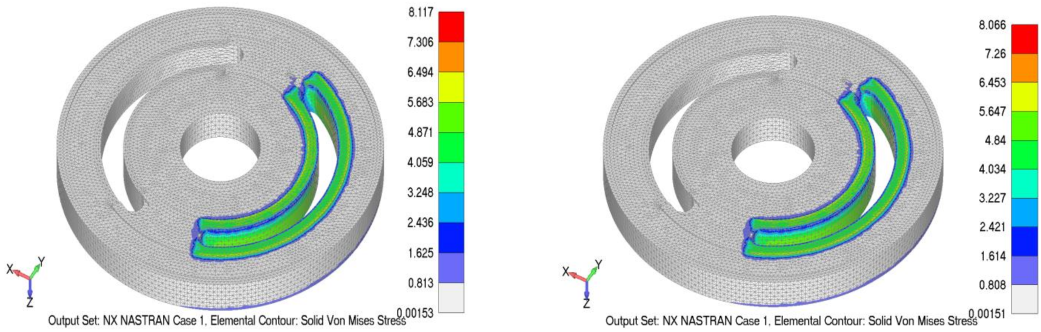

Fig. 8. Distribution of equivalent stress PEEK 1/PEEK2

5. Conclusions

The research results obtained in this study show a high correspondence with the experimental results obtained in the paper (Shaoping, Tomovic and Lei, 2017). Applied mathematical model enables further research with the friction couples cylinder block/valve plate, slipper/swash plate and piston/plunger cavity. Calculations related to the use of PEEK material justified the application of these materials. In addition to the mechanical pressure load, it is necessary to conduct the analysis of the temperature load and deformation in order to optimize the existing structures end thrust piston pumps for water hydraulics.

Water hydraulics is a versatile technology, which can be applied in various applications. That makes it an interesting technology area to be further researched and developed. In water hydraulic system, the first objective should be to develop a piston pump and motor using raw water as pressure medium. The poor lubrication, wear, and erosion in water piston pump (motor) are more likely to happen than in oil hydraulic one election. The experience gained from experimental study on the friction pairs in a pump (motor) will provide good basis for design and development of water hydraulic axial piston pumps and motors. Modern water hydraulic technology is still new and there are a lot of problems to be solved in order to make the technique more widely available for power transmission.

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