Analyses of engineered surfaces for performance improvements of external gear pumps

Paolo Casoli[1], Fabio Scolari[1], Carlo Maria Vescovini[1], Carlo Rossi[2], Antonio Lettini[2]

[1]*Department of Engineering and Architecture, University of Parma, Italy paolo.casoli@unipr.it, fabio.scolari@unipr.it, carlomaria.vescovini@unipr.it*

[2]*Casappa S.p.A., Parma, Italy rossic@casappa.com, lettinia@casappa.com*

Abstract.

In the field of fluid power systems the research is constantly aimed at the development of more efficient components. Electro-hydraulic solutions present an interaction between hydraulic and electrical machine, often with the aim of controlling the delivered flow rate by changing the pump shaft speed over a possibly wide range; these solutions pose new challenges for the design of hydraulic machines. This work focuses on the possibility of extending the working range of external gear pumps by increasing the hydrodynamic bearing capacity in the meatus between gear wheels and lateral plates. The goal is to accomplish this result through the introduction of a textured surface on the lateral plates. Starting from the results of CFD simulations, some physical prototypes have been realized to carry out an experimental verification activity. Bench tests have been then conducted to measure the efficiency of pumps with textured lateral plates, to be compared with the efficiency of standard pumps. The results obtained, showing different behaviours between the samples compared, create the basis for future developments.

Keywords. Textured surfaces, gear pump, laser texturing, dynamic cavitation.

1. INTRODUCTION

In hydraulic systems most of the fixed displacement machines used to generate flow are external gear pumps, since they have high reliability and low cost due to the small number of components. Although they are conceptually simple machines, the design is often difficult, such as the lateral plates, which are crucial to ensure high efficiency for the entire pump [1]. Recently, electro-hydraulic solutions have become a major research topic. These solutions consist in coupling hydraulic and electric machines in order to control the flow rate required by the users by varying the speed of the pump over a wide operating range [2, 3]. Electro-hydraulic solutions could further favour the diffusion of gear pumps, but also pose design challenges, since the components are subjected to more severe working conditions.

This work investigates the possibility of extending the working range of external gear pumps by increasing the hydrodynamic bearing capacity between gear wheels and lateral plates, by means of textured surfaces. A textured surface provides several improvements [4]. Firstly, it allows to generate a greater bearing capacity due to an increased average pressure for hydrodynamic effects. Moreover, a lower coefficient of friction can be achieved by reducing the contact surface. Finally, the textured surface can generate oil wells that ensure greater lubrication of the meatus. All these effects allow to reduce the overall wear and increase the useful life of the machine. In scientific literature there are interesting studies regarding textured surfaces applied to thrust bearings. Rahmani et Al. [5] achieved good improvements in the bearing capacity and frictional force of an axial bearing thanks to numerical study of textured surfaces. Etsion et Al. [6, 7] achieved good numerical results, experimentally validated on a parallel bearing. In order to achieve the benefits of a textured surface, an accurate definition of the geometry is essential. The large number of involved variables that influence performance makes the design phase complex: some of these are the geometric characteristics of the texture, the type of contact, the properties of the fluid and the operating conditions. The study of the fluid meatus has been performed by means of CFD simulations. In previous articles [8, 9], the influence on the bearing capacity of the main geometric characteristics of the texture and the best distribution of the dimples to maximize performances have been studied numerically on a simple reference domain. Starting from previous results, in this work further fluid dynamics simulations were carried out, extending the domain to the meatus between gear wheels and lateral plates inside external gear pumps. Great importance has been attributed to the fluid model. In hydraulic circuits, local cavitation phenomena could occur in particular working conditions that could compromise the operation of the machines. A detailed cavitation model has been implemented to consider both the effect of gaseous and vapor cavitation. The next step was the physical realization of the prototypes. The textures on the lateral plates samples have been made by laser marking, since it is a very flexible technology with an excellent repeatability. The samples have been subsequently measured by means of an optical profilometer to verify the geometric characteristics obtained and to calibrate the process parameters. An experimental test bench activity was then conducted to measure the efficiency of pumps with textured lateral plates, to be compared with the efficiency of standard pumps. The results are very encouraging, since they show different behaviours between standard pumps and pumps with textured components and put the foundations for future developments and insights. The paper is structured as follows. Section II describes the case study, highlighting the advantages and criticalities of external gear pumps; in section III the geometric configuration chosen to carry out the numerical simulations is discussed. Section IV describes the fluid model adopted with particular attention to the cavitation phenomenon. Section V reports the results of the numerical simulations, while section VI describes the experimental activity, both the physical production of the prototypes and the experimental layout of the test bench.

2. CASE STUDY

External gear pumps are conceptually simple machines, but the design is often difficult, especially to ensure good performances at high working pressures. Among the internal components, the lateral plates are two important elements that strongly affect the performances of the machine. They are axial compensation plates that allow for minimum gap heights with the gear wheels to reduce losses due to leakage, improving the volumetric efficiency. They also prevent the lateral plates from coming into direct contact with the gear wheels, avoiding excessive wear of the elements. The equilibrium position of the lateral plates depends on the acting forces, given by the operating conditions of the machine, such as the delivery pressure and the rotational speed. In order to limit leakages from high to low pressure, the lateral plates are usually designed to be inclined more towards the low pressure area: this means that the gap height in the suction area is lower, making the portion of the lateral plate in low pressure critical. Variations in the working conditions can reduce the gap height between the lateral plates and the gear wheels to the point of allowing direct contact between the two components, which is normally avoided due to the establishment of a hydrodynamic bearing capacity that counterbalances the approach of the two surfaces. The direct contact between the aluminum lateral plates and the steel gear wheels generates wear of the lateral plates, risking to seriously damage the component causing a decrease in pump performance.

3. TEXTURED SURFACES

The aim of this research activity is to generate an additional hydrodynamic bearing capacity by means of textured surfaces to avoid, or at least to limit, direct contact between gear wheels and lateral plates. A textured surface has a precise and ordered micro geometry designed to increase some properties, in this case tribological ones. The study focuses on the fluid gap between the gear wheels and the lateral plates, highlighted in Fig. 3.1. Since the low pressure area is the critical one, the texture has been introduced only on this portion of the lateral plates. To investigate the hydrodynamic effects of a textured surface, a numerical CFD study has been performed in the ANSYS® CFX environment. The gap geometry is complex to define due to the position assumed by the lateral plates while the pump is working. It was therefore assumed that the gap is delimited by two parallel surfaces. Previous research [8, 9] have shown that the best geometric layout of the dimples within the domain to maximize the bearing capacity is a configuration called partial texturing. The dimples are placed only on a portion of the entire domain and the best condition is when the textured portion is equal to 45-60% of the entire domain.

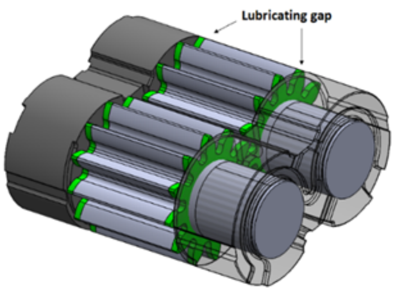

Figure 3.1. Assembly of gear wheels and lateral plates. The fluid gap is highlighted in green.

In this work, a grid of channels defines a sectoral structure where each sector has been partially textured. Figure 3.2 shows a portion of the aforementioned surface: the dimples are highlighted in green, while the channels, with greater depth, are in blue. The size of the sectors has been defined considering the geometry of the tooth, which, being an involute profile, narrows towards the extremity: for this reason, the sectors at greater distance from the rotation axis have a smaller angular dimension. Geometric dimensions cannot be disclosed for confidentiality reasons.

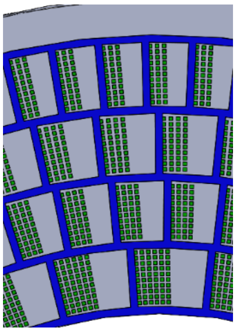

Figure 3.2. Geometry characterized by the sequence of dimples (in green) and channels (in blue).

4. FLUID MODEL

A three-phase fluid model, consisting of liquid, gas and vapor, has been adopted in the simulations. In accordance with the law of mass conservation, the sum of the mass fractions of each phase must be unitary. To also include the effects of gaseous cavitation, the liquid phase was modelled as a variable composition mixture of oil and dissolved air.

4.1. Gaseous cavitation

Since non-condensable gases can be dissolved in liquid or in free form, it is required to know the variation of the mass fractions of both free and dissolved air. So, two additional convection-diffusion equations have been added to the CFD code, one for non-condensable gases in the gaseous phase and one for those dissolved in liquid. The discussion of the model is reported in [8]. ρ is the fluid density and U the velocity.

$$\frac{\partial(\rho f_{g,g})}{\partial t} + \nabla \cdot \left(\rho \vec{U} f_{g,g} - D_{g,g}(\nabla f_{g,g})\right) = \dot{S}_{DA} \quad (4.1)$$

$$\frac{\partial(\rho f_{g,l})}{\partial t} + \nabla \cdot \left(\rho \vec{U} f_{g,l} - D_{g,l}(\nabla f_{g,l})\right) = -\dot{S}_{DA} \quad (4.2)$$

The source term $\dot{S}_{DA}$ controls the transition between the two states:

$$\dot{S}_{DA} = R_d - R_a = \begin{cases} C_d \rho_g (p_{equil} - p_g)(1 - f_{g,g}) f_{g,l} \\ C_a \rho_g (p_g - p_{equil})(f_{g,l,lim} - f_{g,l}) f_{g,g} \end{cases} \quad (4.3)$$

R_d and R_a are the mass rate for desorption and absorption. The equilibrium pressure p_{equil} controls the process and is given by the sum of the vapor pressure and the partial pressure of the gas. The release of air occurs when the partial pressure of the gas is lower than the equilibrium one, while the reabsorption when the pressure is higher. C_d and C_a are empirical coefficients that influence the speed with which the associated phenomenon occurs.

4.2. Vapor cavitation

To also include the effects of vapor cavitation, a transport equation for vapor was used, starting from the Rayleigh-Plesset equation. The complete description of the model is given in [7]. The equation that expresses the interphase mass transfer rates for condensation is:

$$\dot{m}_{fgc} = F\frac{3r_g\rho_g}{R_B}\sqrt{\frac{2}{3}\frac{|p_v - p|}{\rho_l}}\,sign(p_v - p) \tag{4.4}$$

And for vaporization:

$$\dot{m}_{fgv} = F\frac{3R_{nuc}(1 - r_g)\rho_g}{R_B}\sqrt{\frac{2}{3}\frac{|p_v - p|}{\rho_f}}\,sign(p_v - p) \tag{4.5}$$

where R_B represents the bubble radius, p_v is the pressure in the bubble, p is the pressure in the liquid surrounding the bubble, ρ_f is the liquid density, and σ is the surface tension coefficient between the liquid and air, R_{nuc} is the volume fraction of the nucleation sites. F is a parameter that determines the speed of the process and can be different in case of condensation, F_c, or vaporization, F_v. The liquid modelled in the CFD simulations is an ISO VG-46 hydraulic oil, which is a complex mixture of hydrocarbons, the main properties are: density 850 kg/m^3 and kinematic viscosity 46 mm^2/s at 40°C. The parameters of the cavitation model are reported in Table I and have been identified through a previous experimental activity, focused on the flow through a fixed orifice [10].

Table I Cavitation parameters used in numerical simulations

Vapor pressure	**R_b**	**R_{nuc}**	**F_v**	**F_c**	**C_d**	**C_a**
0.2 bar	0.5 µm	5e-4	0.9	0.01	2	-0.1

5. NUMERICAL RESULTS

During the rotation of the gear wheel the portion of the textured surface changes in the domain: the simulations were performed considering different angular positions of the tooth, spaced 2° from each other. The boundary conditions are open boundary with zero relative pressure for the perimeter walls of the domain, while the upper plane is a moving wall with a no slip condition. The rotational speed of the moving plane is assumed to be 2500 r/min. The fluid motion is assumed to be laminar, due to the low height of the gap and the high viscosity of the hydraulic oil, assumed at 40 °C. The fluid domain has been discretized using a structured mesh, whose characteristics have been established following a sensitivity analysis. Figure 5.1 shows the absolute pressure contours relating to one angular position with a gap height equal to 10 µm. The rotational direction of the moving plane is clockwise. In the configuration of partial texturing, in each sector an increasing pressure ramp is generated to achieve an overall overpressure. The grid of channels permits to make each sector independent from the others by restoring the boundary conditions: in this way all sectors provide a contribution that allows the entire surface to generate a positive bearing capacity, calculated as the integral of pressure on the moving plane.

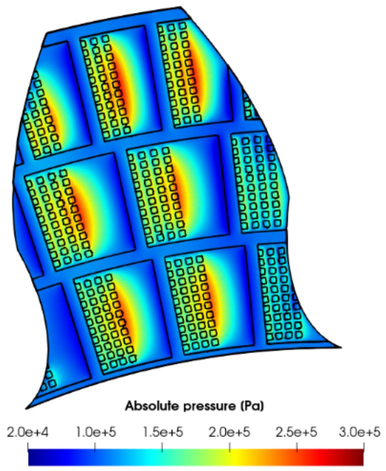

Figure 5.1. Pressure contours. Gap 10 µm and rotating speed 2500 r/min

Figure 5.2 shows the force generated by the surface in different positions assumed by the tooth during rotation. For confidentiality reasons, the bearing capacity was normalized with respect to the maximum value. The bearing capacity changes according to the angular position of the tooth. The reason for this trend is due to the number of sectors present in the computing domain which is not always constant in the various positions considered. This trend is maintained for all the gap heights but intensifies as the gap decreases.

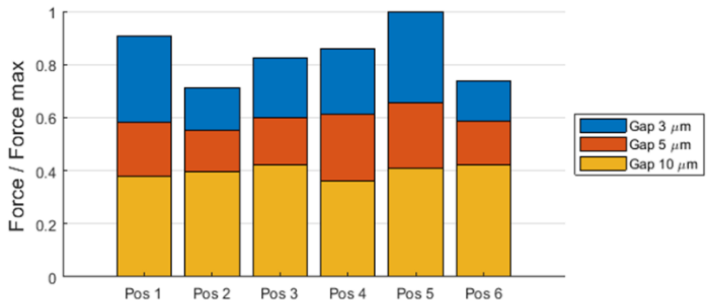

Figure 5.2. Bearing capacity for different values of the gap.

The graph of Fig. 5.2 also indicates that the force increases as the gap decreases. To better quantify this feature, Fig. 5.3 shows the dimensionless force averaged over the various positions considered: the trend as the gap decreases rises more than linearly and represents a very useful aspect capable of limiting the further approach between the two coupled surfaces.

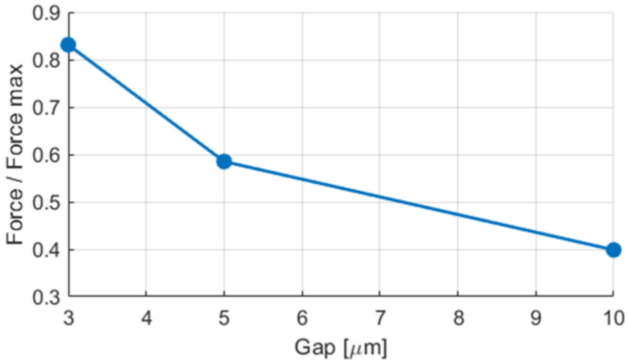

Figure 5.3. Bearing capacity averaged over the six angular positions as a function of the gap.

5.1. Cavitation consideration

The numerical model allows to calculate the distribution of the gaseous phase, both of vapor and of free air. The Fig. 5.4 shows the volume fraction of vapor generated in the case of a 3 µm gap. Vapor is generated locally in small portions of the domain. Since, as shown in the pressure contour, the channels represent the area where the pressure is lower, the vapor tends to be generated in this portion of the domain where the saturation pressure is reached. In the angular position considered (also representative of the other positions), vapor is formed only in the channels towards the outlet, since there is no subsequent sector that contributes to increasing the pressure. The sectors in the centre of the domain increase the pressure in the adjacent channels sufficiently not to reach the saturation pressure.

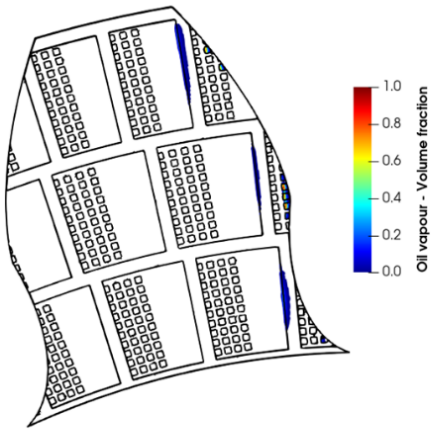

Figure 5.4. Oil vapor volume fraction. Gap 3 µm, rotating velocity 2500 r/min. Only the portions of the mesh where the volume fraction of vapor is greater than 10% are highlighted.

Free air also tends to be concentrated more in the channels, since the pressure is the lowest within the domain, as shown in Fig. 5.5. Since the free air reabsorption process is not instantaneous, part of the free air is dragged inside the sectors before being completely reabsorbed by the pressure increase.

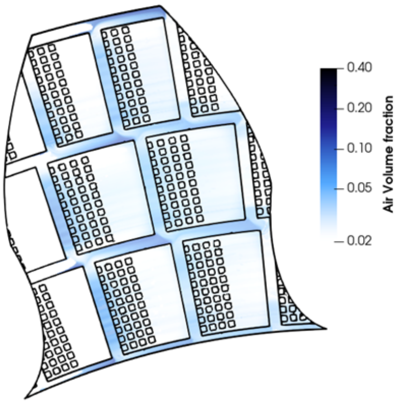

Figure 5.5. Air volume fraction. Gap 3 µm, rotating velocity 2500 r/min. Only the portions of the mesh where the volume fraction of air is greater than 2% are highlighted.

The model permits to verify that the chosen texture configuration allows to minimize the effects of vaporous cavitation, confining its onset locally, without negative effects on the pressure field generated by the texture. Furthermore, even the gaseous cavitation manifests itself with low intensity and does not affect the pressure profile given by the texturing.

6. EXPERIMENTAL ACTIVITY

6.1. Samples manufacturing

The texture has been created on the portion of lateral plates corresponding to the suction area by means of laser marking technology. For this task a 20W fiber laser source in pulsed regime has been adopted. Details regarding the processing parameters cannot be disclosed for confidentiality reasons. The samples have been measured, before the experimental tests, using an optical profilometer in order to verify that the geometry obtained is the desired one. The profilometer, available at the Department of Engineering and Architecture of the University of Parma, is a Taylor Hobson CCI MP-L. In Fig. 6.1 a picture of a textured lateral plate sample is presented: the textured sectors delimited by the grid of channels can be seen.

Figure 6.1. Photo of the lateral plate.

Fig. 6.2 shows the 3D profile of the surface obtained by the profilometer. The measurements of the surface are essential to calibrate the process parameters to obtain a geometry as close as possible to the theoretical one. Laser marking leaves burrs in correspondence with the removed surface, which have been almost totally eliminated by a subsequent mechanical finishing process.

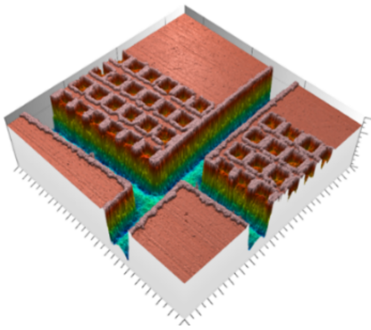

Figure 6.2 3D profile measured after the mechanical finishing process.

The textured samples have been then assembled into external gear pumps made by Casappa S.p.A.

6.2. Test

The tests have been performed on the test bench present in the Laboratory of the Department of Engineering and Architecture of the University of Parma. Figure 6.3 shows a picture of the test bench set up and the respective ISO layout diagram is reported in Fig. 6.4.

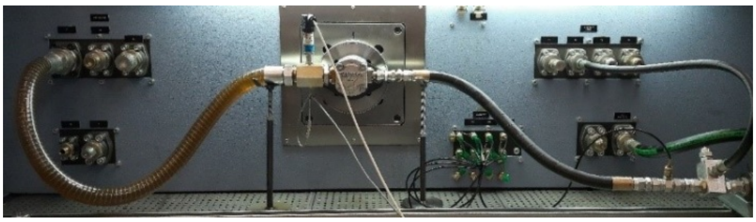

Figure 6.3. Picture of the test bench set up.

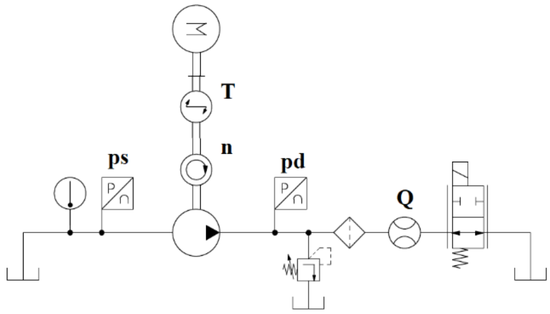

Figure 6.4. ISO scheme of the circuit layout.

Table II lists the sensors models used and their main characteristics. The overall efficiency was calculated by measuring: torque, inlet pressure, delivery pressure, flow rate and shaft speed.

Table II Sensors installed in the test bench and relative features

Variable	Sensor	Model	Main Features
ps	Pressure Transducer	Wika S-10	0 – 10 barA ±0.5%FS
pd	Pressure Transducer	Danfoss MBS 1250	0 – 400 bar ±0.5%FS
Q	Flow Meter	VSE VS 1	0-80 l/min ± 0.3% measured value
n	Speed sensor	HMB T10FS	accuracy class 0.05
T	Torque sensor	HMB T10FS	accuracy class 0.05

6.3. Results

To assess whether the pumps with textured components have better performances than the traditional ones, it is necessary to carry out tests in severe conditions. In normal operating conditions, the wear on the lateral plates does not occur, even after long-term tests. Therefore, tests conducted under out-of-specification conditions, where a direct contact between the lateral plates and the gear wheels takes place, would be necessary. However also in this case, a decrease in the overall efficiency of the pump is difficult to associate exclusively to the textured components, because they are also affected by other effects (for examples by radial clearances). Moreover, depending on the type of tests and the test conditions, a measurable wear on the lateral plates due to the direct contact can be observed only after many working cycles, for the progressive removal of material in seizure conditions. In order to achieve the direct contact with the gear wheels also at normal operating conditions, to emphasize the effect of textured plates and to reduce the test time, the lateral plates have been specially modified, in order to increase the axial and tilting forces. The test method consists in characterizing the performances of the machine in fixed pressure points (ranging from 120 bar to 240 bar, 20 bar step) at increasing pump speed (from 1000 r/min to 3000 r/min, 500 r/min step). The contact, and the associated seizure of plates, is then reached at a certain combination of pressure and speed. The test procedure has been repeated twice to show possible marked differences between the two cycles. Figure 6.5 shows the trend of the overall efficiency of a pump with modified lateral plates, but without texturing: the efficiency of the first cycle is represented in a continuous line, the second in dashed line. The values have been divided by a reference value for confidentiality reasons. To make the comparison between the two data series clearer, curves of only three speeds are shown. As the rotation speed decreases, the difference between the efficiencies increases, such that the efficiency of the machine after two cycles is significantly lower than in the first cycle. This is a clear consequence of components internal wear and represents a proof that the test is such as to reach critical conditions.

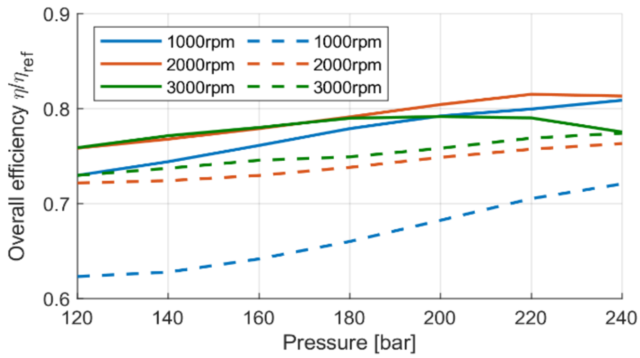

Figure 6.5. Overall efficiency of a pump with modified lateral plates, but without texturing. Solid line represents Cycle I; Dashed line represent Cycle II

Similarly, Fig. 6.6 shows the overall efficiency of a pump with modified lateral plates, but with textured surface. In this case, the differences between the efficiencies obtained in the two cycles are very slight. This means that despite the severe test conditions, textured side plates pumps are not as damaged as traditional ones.

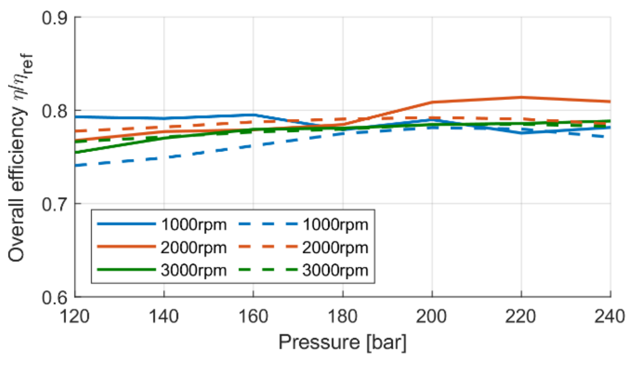

Figure 6.6. Overall efficiency of a pump with textured lateral plates. Solid line represents Cycle I; Dashed line represent Cycle II

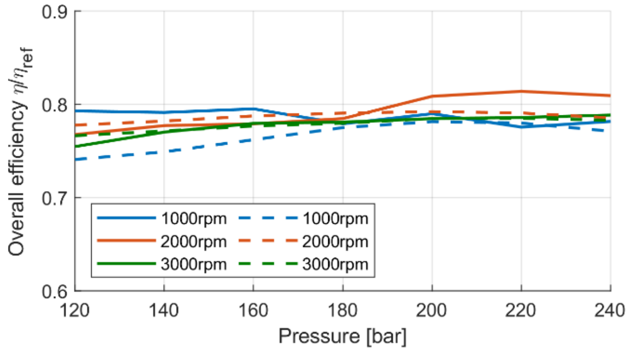

Figure 6.7. Overall efficiency of a pump with modified lateral plates and with textured surface. Solid line represents Cycle I; Dashed line represent Cycle II

Figure 6.7 shows the comparison between the results of pumps without textured components, and pumps with textured lateral plates. The results shown are the average of those obtained on all tested samples. A synthetic parameter has been introduced to quickly assess if there are significant differences between the two cycles: the parameter is the average of the overall efficiency calculated for each test point of each cycle. For confidentiality reasons, the result has been divided by a reference value.

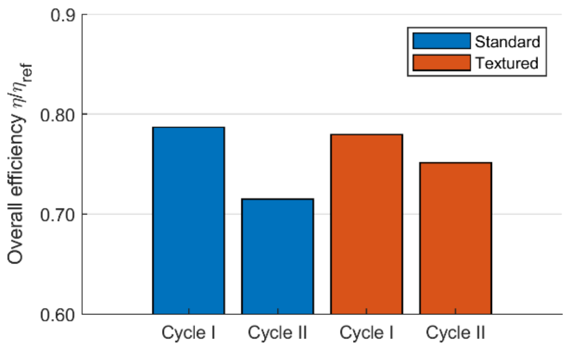

Figure 6.8. Comparison between pumps without textured lateral plates and pumps with textured lateral plates: the values are averaged between all samples tested.

The chart, Fig. 6.8, confirms and clarifies what observed on the graphs of Fig. 6.6 and Fig. 6.7. The traditional pumps show a very marked reduction in efficiency, equal to -7%. This is a sign that the configuration of the components and the test conditions were such as to reach seizure conditions. Under the same test conditions, the pumps with textured lateral plates show only a slight decrease in efficiency, equal to -2.7%. These results are very encouraging because they show that the introduction of a textured surface promotes better performances and create the basis for future developments. Further validation tests will be performed to confirm the repeatability of the results, while also varying the operating conditions.

7. CONCLUSIONS

In this work, the results of a research activity on the application of textured surfaces applied to gear pumps are presented. The texture was made on the lateral plates to generate an additional bearing capacity with the aim of avoiding or at least limiting the approach between gear wheels and lateral plates, in order to reduce wear of the components and increase the useful life of the machine. A numerical study with CFD simulations permits to define the best geometric configuration to set up an experimental verification campaign. The samples were made by laser marking, since it is a very versatile technology with excellent repeatability. Bench tests were carried out to compare the performances between pumps with traditional lateral plates and pumps with textured components. The results showed that the two configurations behave differently: in general, pumps with textured lateral plates show better performances, which in any case will require further checks in the future.

ACKNOWLEDGMENT

The authors would like to thank Simone Mazzucato (Sisma S.p.A, Italy) for the support given in the laser marking processes on the tested prototypes.

8. REFERENCES

[1] J. Ivantysyn, M. Ivantysynova, Hydrostatic Pumps and Motors, Principles, Designs, Performance, Modelling, Analysis, Control and Testing. Akademia Books International. New Delhi, India, 2002.

[2] A. Malvasi, R. Squarcini, G. Armenio, A. Brömmel, Design process of an electric powered oil pump. Autotechreview. 2014. Doi: 10.1007/s38313-012-0236-0.

[3] J. H. Kim, S. G. Kim, The Flow Rate Characteristics of External Gear Pump for EHPS. Proceedings of the 4th International Conference on Intelligent Systems, Modelling and Simulation, Bangkok, Thailand. 2013. Doi: 10.1109/ISMS.2013.113.

[4] T. Ibatan, M. S. Uddin, M. A. K. Chowdhury. Recent development on surface texturing in enhancing tribological performance of bearing sliders, Surface & Coatings Technology, 2015, Volume 272, pp 102–120. Doi: 10.1016/j.surfcoat.2015.04.017

[5] R. Rahmani, A. Shirvani, H. Shirvani, Optimization of Partially Textured Parallel Thrust Bearings with Square-Shaped Micro-Dimples, Tribology transactions, 2007, 50:3, 401-406. Doi: 10.1080/10402000701429261

[6] I. Etsion, G. Halperin, V. Brizmer, Y. Klingerman, Experimental investigation of laser surface textured parallel thrust bearings, Tribology Letters, 2003, Volume 17, pp 295–300.

[7] Brizmer V, Kligerman Y, Etsion I, A Laser Surface Textured Parallel Thrust Bearing, Tribology transactions, 2003, 46:3, 397-403, DOI: 10.1080/10402000308982643

[8] P. Casoli, F. Scolari, C. Rossi, M. Rigosi, A cfd design of engineered surface for tribological performance improvements in hydraulic pumps, 12th International Fluid Power Conference (12. IFK). Dresden, October 12 – 14, 2020. Doi: 10.25368/2020.41

[9] P. Casoli, F. Scolari, M. Rundo, A. Lettini, M. Rigosi, CFD Analyses of Textured Surfaces for Tribological Improvements in Hydraulic Pumps. Energies 2020, 13(21), 5799. Doi: 10.3390/en13215799
[10] P. Casoli, F. Scolari, M. Rundo, Modelling and Validation of Cavitating Orifice Flow in Hydraulic Systems. Sustainability 2021, 13(13), 7239. Doi:10.3390/su13137239

Biographies

Paolo Casoli received M.S. degree in mechanical engineering at the University of Bologna (Italy) in 1990. He became associate professor in 2001 and currently is a full Professor of Fluid Machinery at the Department of Systems Engineering and Industrial Technologies at the University of Parma (Italy). His research interests include modelling and experimental analysis of positive displacement pumps for fluid power applications. The research is focused on both the machines and the circuits connected to the machines.

Carlo Maria Vescovini received M.S. degree in Mechanical Engineering at the University of Parma (Italy) in April 2021. He currently is an Industrial Engineering Ph.D. student at the Department of Systems Engineering and Industrial Technologies University of Parma (Italy). His research concerns power hydraulics systems and machines. In particular, his work focuses on positive displacement pumps, their modelling and testing. Furthermore, part of its commitment is aimed at reducing the noise and pulsations produced by of volumetric machines through passive and active devices.

Fabio Scolari received Ph.D. in Industrial Engineering at the University of Parma (Italy) in 2022. His fields of research are hydraulic systems and components. His main research activity consists in the study of techniques for increasing the hydrodynamic bearing capacity between lubricated couplings inside hydraulic pumps.

Antonio Lettini graduated in Mechanical Engineering at the Polytechnic University of Turin (Italy) in 2000 and specialized in the field of Fluid Power at the Fluid Power Research Laboratory in Turin before joining Casappa SpA in 2003. Since 2008 he is in charge of the R&D Department Management, now as Group R&D Director. He earned an MBA at Bologna Business School in 2010.

Carlo Rossi graduated in Mechanical Engineering in 1998 at the University of Parma (Italy). He started his professional career first dealing with the management of maintenance in manufacturing companies, then with aluminium die-casting in the field of electric motors. Starting from 2007, he moved to the fluid power field joining Casappa SpA and since 2018 he has been focusing on new technologies and production processes for gear pumps and piston pumps.