

HIGH EFFICIENCY AT 200 – 2000 RPM AND 10 – 30 MPa: VANE-IN-GROOVE PUMPS WITH ADAPTIVE ROTOR

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ABSTRACT

Paper presents a development aimed at substantial reduction of friction losses and leakages level in vane pumps with a working chamber made in annular groove in a rotor face. Since sealing surfaces of a rotor and a housing are flat and vanes are fixed in the annular groove rigidly working fluid leakages are very small. Thus this type of vane pumps (called Vane-In-Groove) achieves high volumetric efficiency at wide range of rotation speed and operational pressure.

The new rotor design (called adaptive) comprises two parts: working and supporting, and provides Vane-In-Groove pump with good hydrostatic axial balancing of both parts of adaptive rotor. This allows to reduce friction forces between rotor parts and cover plates of the housing. Thus with adaptive rotor design high mechanical efficiency can be reached as well.

Paper describes one type of Vane-In-Groove pump architecture. It has an adaptive rotor located between housing cover plates and is preferable for variable displacement machines.

The tests equipment, schematic diagram and procedure for volumetric and overall efficiency measurement are presented as well as the tests results for 28 cm³ pump. The test results illustrate high volumetric and overall efficiency at 200 – 2000 RPM and 5 – 30 MPa.

KEYWORDS: high overall efficiency, high mechanical efficiency, high volumetric efficiency, vane pump/motor, Vane-In-Groove

1. INTRODUCTION

Vane pump with a working chamber located in annular groove made in one of rotor faces (called by the authors Vane-In-Groove type of pump architecture) offers a number of advantages compare to a vane pump of conventional architecture.

Vane-In-Groove pump has a working chamber formed by four surfaces: in radial direction – by cylindrical walls of the annular groove, in axial direction – by the bottom of the annular groove and a working cover plate of a pump housing, aligned to a rotor face (see Fig. 1).

Such working chamber allocation defines the following advantages of this pump:

- major working chamber sealing is made by a plane-to-plane clamping of a rotor face to a working cover plate of a pump housing;
- rotor is hydraulically balanced in radial direction due to the fact, that working fluid locked in the high pressure area stresses with the same force to the opposite walls of the working chamber, which are the parts of the rotor.

Both technical features in combination with rigidly fixed in the annular groove vanes provide with the following custom advantages:

- high operational pressure (typical for piston pumps);
- uniform output flow with no kinematical ripple;
- high volumetric efficiency at wide range of rotation speed and operational pressure.

Vane-In-Groove (hereinafter VIG) pump can be done reversible, of variable displacement and can be used as a motor.

In the last case VIG architecture provides a motor with useful custom features such as:

- steady torque at wide range of rotation speed;
- low rotation speed at still high volumetric efficiency.

However, VIG architecture itself does not provide with axial balancing of a rotor. Working chamber sealing requires application of significant force to the side of a working cover plate opposite to a working chamber. This force must exceed the fluid pressure forces acting to a working cover plate from a working chamber. This in its turn results in significant power losses caused by friction between a working cover plate and a rotor face when using mechanical means of a cover plate pressing. Some improvement can be achieved using working cover plate with a hydrostatically balanced axially movable sealing element but friction losses remain significant and overall efficiency of that pumps does not exceed 60 %.

Detailed analysis of the forces acting on a rotor and a working cover plate with an axially movable sealing element is given in [7].

Real solution of friction forces problem can be achieved with the new rotor design called Adaptive Rotor.

2. VANE-IN-GROOVE PUMP WITH ADAPTIVE ROTOR

The idea of Adaptive Rotor is that a rotor comprises two parts (Fig. 1 and Fig. 2) – working and supporting. Annular groove is made at a face of the working part of the rotor, forming a working chamber. Working part of the rotor is in sliding insulating contact with sealing elements of working cover plate (not shown in Fig.1), where forward and backward transfer limiters are located. Supporting part of the rotor has a set of supporting cavities and functions as movable sealing member being in sliding insulating contact with sealing elements of supporting cover plate (not shown in Fig.1). Working and supporting parts of the rotor are connected to each other so, that they rotate synchronously, but can make small mutual axial shifts and tilts to provide a

sliding insulating contact between the rotor parts and both cover plates as rotation of the rotor. Special force chambers of variable axial length are made between the working and supporting parts of the rotor. Each force chamber is connected to the working chamber and to the supporting cavity of the supporting part of the rotor.

Thus it transmits the fluid pressure from the part of the working chamber to the corresponding supporting cavity making the whole rotor assembly “pressure transparent”. The area of the force chamber cross-section is chosen so that the fluid pressure forces, acting to the working part of the rotor from the working chamber and from the force chambers are balanced. Similarly, the area of a supporting cavity based on the force chamber cross-section area is chosen so that the fluid pressure forces, acting to the supporting part of the rotor from the supporting cavities and from the force chambers are balanced. Thus axial balancing of both working and supporting parts of the rotor is achieved. Full pressure force now is applied to the housing rather than the rotor. By choosing the abovementioned areas any pressing forces between the rotor parts and corresponding cover plates can be achieved. These pressing forces can be chosen as small as required for insulating each part of the rotor.

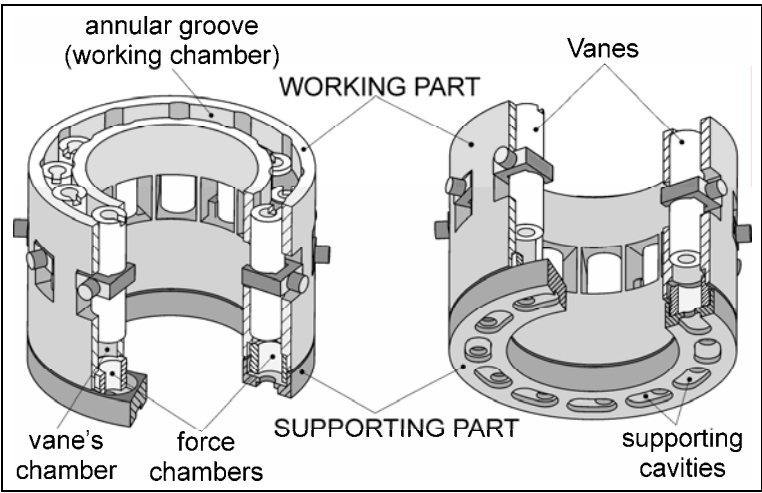


Figure 1: Adaptive Rotor design

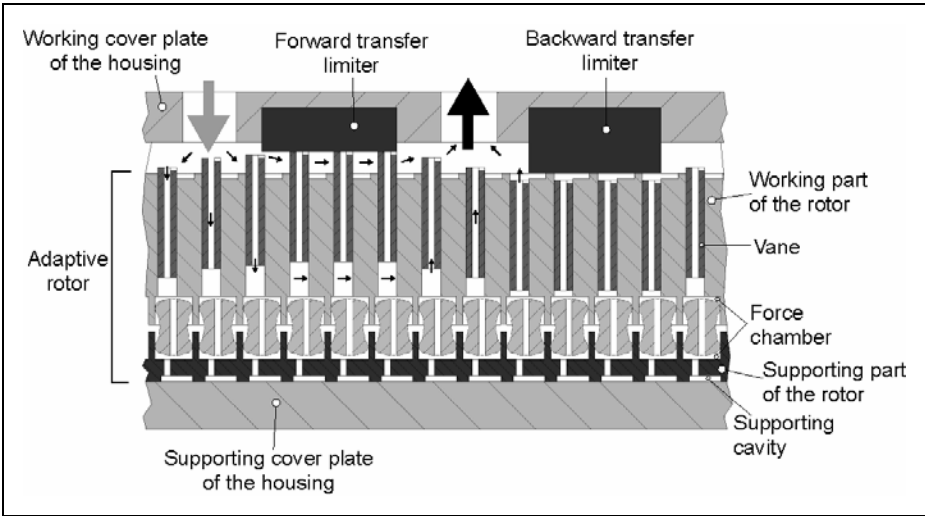


Figure 2: Vane-In-Groove pump with Adaptive Rotor – circular development along the annular groove

Detailed description of Adaptive Rotor design for a VIG machine as well as analysis of the forces acting on a rotor and a working cover plate is given in [7]. The Adaptive Rotor principle offers wide range of a VIG machine embodiments depending on requirements the machine must meet. Some embodiments are described in details in patent application [8].

To verify the idea of Adaptive Rotor in real-life a number of pump prototypes have been designed assembled and tested on our internal testing stand. All they have shown functionality and good performance.

3. TEST INSTALLATION AND PROCEDURE

Figure 3 presents scheme of the internal testing stand and Fig. 4 shows it's photos. The test circuit is closed type without backup. Industrial oil similar to HLP 46 was used as a working fluid. The water cooling system working on counter-current flow principle kept up the fluid temperature within the limits of 30 ± 5 °C. Adjustable orifice was used as a load. Maximal drive power provided by the electromotor was 30 kW. Outlet pressure, oil temperature, pump housing temperature at 2 points were recorded as well as outlet and drainage flow rates were measured by gravimetric method.

The test matrix was defined as follows:

- operating pressure: 10, 20 and 30 MPa
- rotation speed: 200, 800, 1500 and 2000 RPM

Investigated parameters were measured for each value of the rotation speed against the outlet pressure.

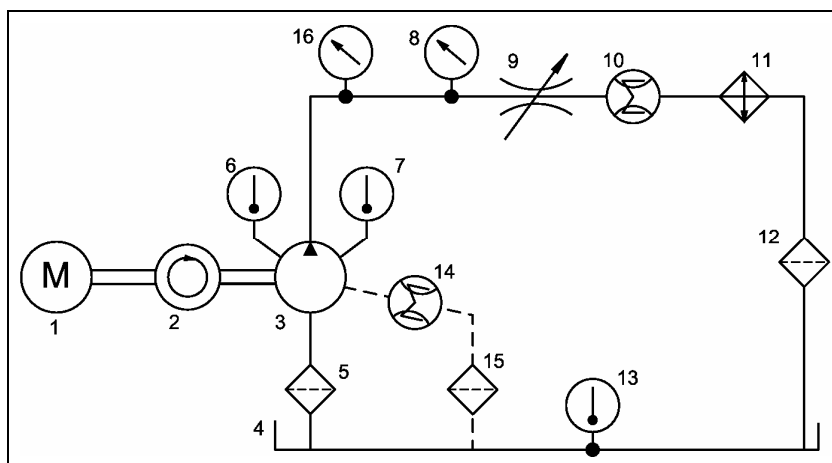


Figure 3: Scheme of the internal testing stand (auxiliary and safety equipment is not shown) 1– electromotor, 2 – tachometer, 3 – tested pump, 4 – tank, 5, 12, 15 – filters, 6, 7, 13 – thermometers, 8 – pressure sensor, 9 – adjustable load throttle, 10, 14 – flowmeter, 11 – counter-current flow cooler, 16 – pressure gauge

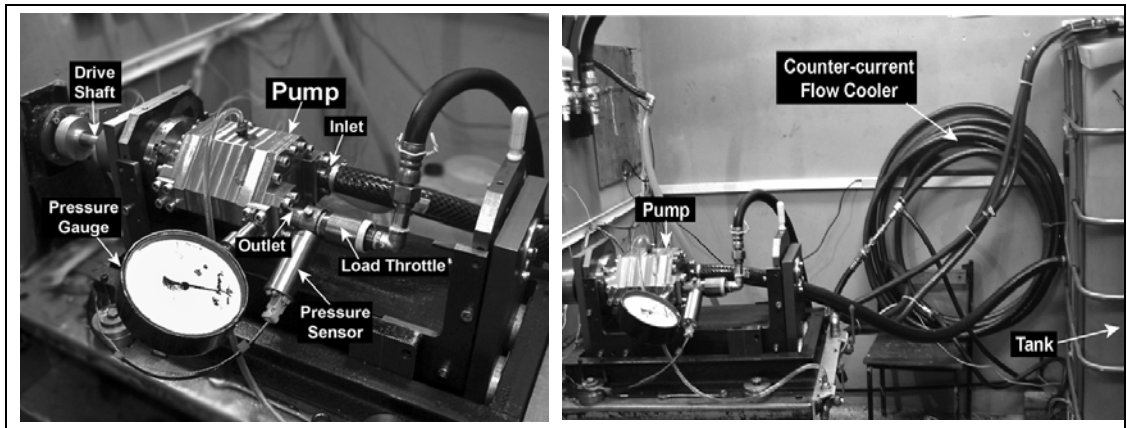


Figure 4: Photos of the internal testing stand (the electromotor is installed in adjacent room)

4. TEST RESULTS

The volumetric efficiency and overall efficiency were evaluated at stationary working points of the test matrix. All findings for each investigated parameter are presented as a set of curves, so that every curve in a set represents one parameter as a function of outlet pressure at constant rotation speed.

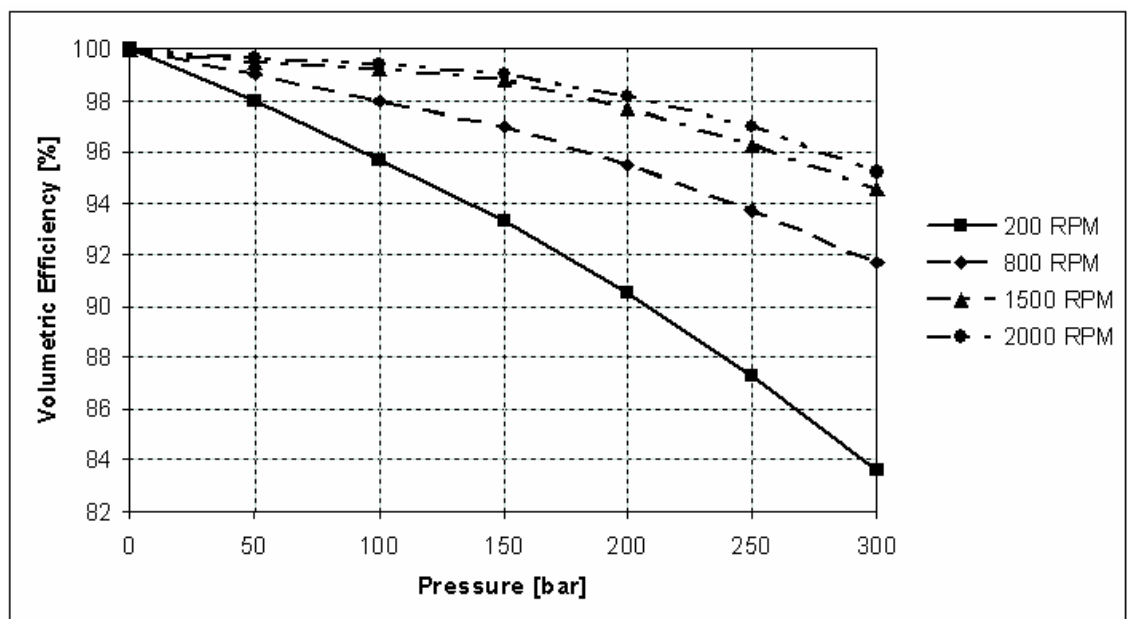


Figure 6: Evaluated volumetric efficiency against outlet pressure for 200, 800, 1500 and 2000 RPM

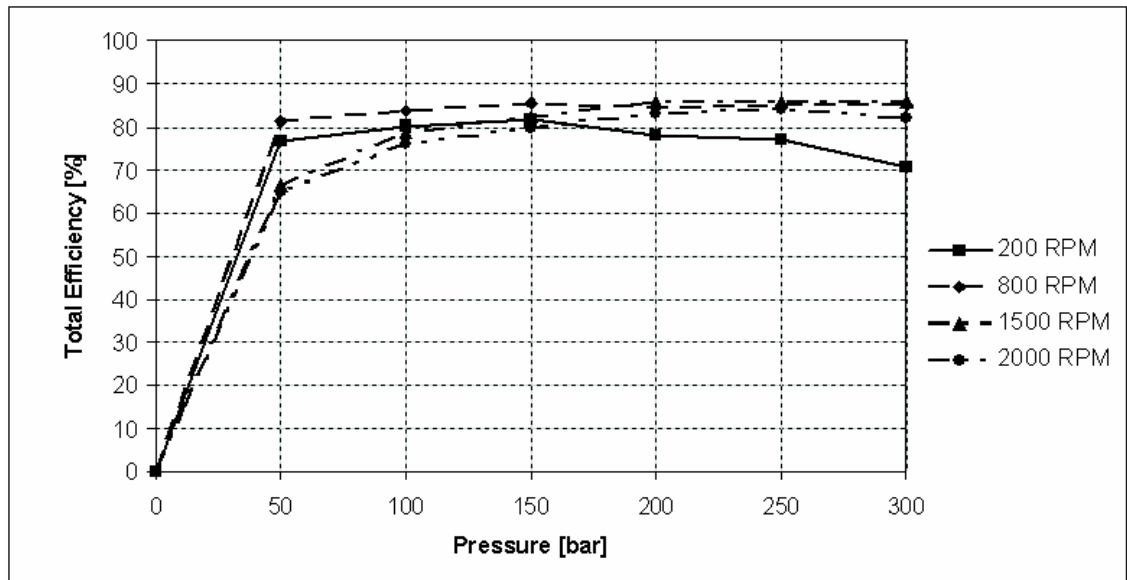


Figure 7: Evaluated overall efficiency against outlet pressure for 200, 800, 1500 and 2000 RPM

5. CONCLUSION

Data presented in 4 show high volumetric and overall efficiency of a VIG pump with Adaptive Rotor at wide range of rotation speed and operational pressure suitable for most of common fluid power applications. In fact a VIG pump with Adaptive Rotor combines high volumetric and overall efficiency proper to a piston pump with uniform output flow proper to a vane pump. When a VIG machine used as a motor it can deliver uniform rotation, constant torque and high overall efficiency at low rotation speed.

6. REFERENCES

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