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THE INFLUENCE OF CINEMATIC ON PERFORMANCES OF PROGRESSIVE CAVITY PUMPS

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ABSTRACT. Progressive cavity pumps have different applications in various industrial fields, as their high reliability and the possibility of circulate high viscosity fluids with solids laden. Increasing efficiency of PCP's is a constant concern of producers. The study of cinematic on performances of pumps offers the possibility to optimize constructive and functional of these pumps with effect the built up of benchmarks.

ВЛИЯНИЕТО НА КИНЕМАТИКАТА ВЪРХУ РАБОТАТА (ДЕЙСТВИЕТО) НА ПОМПИ С НАРАСТВАЩА КУХИНА

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РЕЗЮМЕ. Помпите с нарастваща кухина намират широко приложение в различни области на промишлеността, тъй като те са много надежни при циркулиране на течности с висок вискозитет при товари с твърди вещества. Нарастване ефективността на работа на тези помпи е постоянна грижа на производителите. Изследването на кинематиката при работа на помпите предлага възможност за оптимизиране на конструкцията и функционалността им с маркиран положителен ефект при сравнение.

Introduction

PCP's are a category of hydrostatic generators with a wide area of usage in various branches of the industry. This fact is due to their capacity to vehiculate continuous flow without pulsations which will generate wear - increased reliability – and to vehiculate multiphase fluids with a high content of solids (up to 80%).

Because there are a lot of advantages, PCP's developed in a wide range and there are used as well as for production of oil and in areas as mining, petrochemical, paper industry, food industry.

For oil production are mainly used for production of fluids with wide values of viscosities, flow of solids laden fluids, production of flooded reservoirs, and those for mining domain are used for removal of underground waters.

Removal of underground waters impose the usage of pumps capable to vehiculate large volumes of fluids at very constant flow; for this kind of job the most used are progressive cavity pumps and centrifugal pumps.

Even if centrifugal pumps offers the biggest flow, boundaries as: depth of pump as electrical losses through cable, high costs, temperature, difficulties in vehiculation of fluids with solids laden are reducing reliability of centrifugal pumps, being legitimate the usage of PCP's.

Concerns as the increase of elastomer's durability to abrasion, gases, high temperatures, choosing the right materials for metallic parts (pump it self, rotor) made the object of a lot of studies. In this paper it will be analyzed the possibility of increasing performances of PCP's by modifying geometry and cinematic.

Geometrical elements of PCP are presented in Fig. 1.

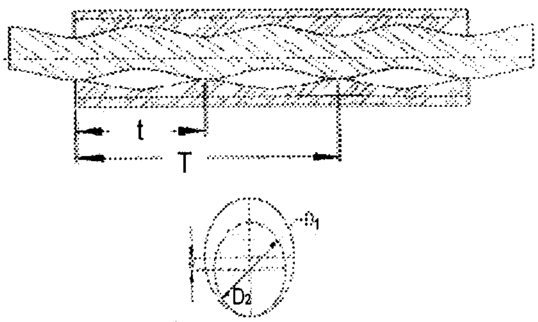


Fig. 1. Dimensional elements of progressing cavity pumps: T- stator pitch, t- rotor pitch, D_1- stator diameter, D_2- rotor diameter

The geometry of PCP's is very complicated which implies high costs with fabrication technology. This caused a wider spread of PCP's with cinematic report 1/2.

The growth of technology from the last decades offered the possibility of introduction PCP's with cinematic report >1/2.

Mathematical model

Classic PCP's have a rotor as mobile element which will rotate around stator's axis (conveyance motion) and a rotation motion around his own axis (relative motion).

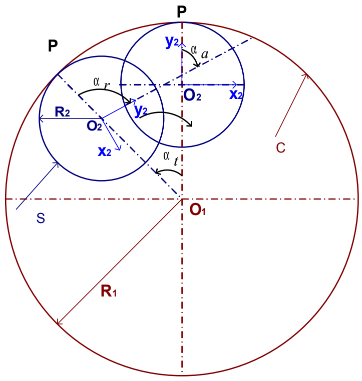


Fig. 2. Progressing cavity pumps cinematic (C- central wheel; S- satellite; P- gear pole)

The segment between centers O1 and O2 (arm port - satellite) is rolling without sliding inside central wheel (convey movement) with angular speed ω_t.

In the same time, the system $x_2o_2y_2$ (together with satellite) execute a rotation motion with the arm port satellite (relative movement) with angular speed ω_r.

Composing the motions the satellite will develop a rotation motion absolute through instantaneous axis of rotation which passes through pole of driving P.

Absolute rotational speed:

$$\omega_a = \omega_r - \omega_t \qquad (1)$$

This is deducted from

$$\alpha_a = \alpha_r - \alpha_t \qquad (2)$$

Where:

- α_a : absolute rotation angle
- α_r : satellite vs. port satellite arm, rotational angle
- α_t : angle which rotate arm O_1O_2.

Because the satellite is rolling without sliding, arcs PM and P'M' will be even:

$$\begin{cases} R_1 \cdot \omega_t = R_2 \cdot \omega_r \Rightarrow \omega_t = \dfrac{R_2}{R_1} \cdot \omega_r = i \cdot \omega_r \\ \omega_a = \omega_r - \omega_t \end{cases} \Rightarrow$$

$$\omega_a = (1 - i)\omega_r = \left(1 - \frac{z_2}{z_1}\right) \cdot \omega_r \qquad (3)$$

Where

- $z_1 = z_2 + 1$;
- z_1 : number of beginning stator
- z_2 : number of beginning rotor

From (3) relative speed and transportation

$$\begin{aligned} \omega_r &= z_1 \cdot \omega_a \\ \omega_t &= z_2 \cdot \omega_a \end{aligned} \qquad (4)$$

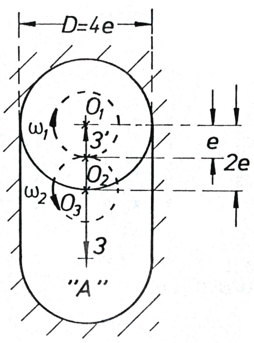
Replacing angular speed with rotational speed:

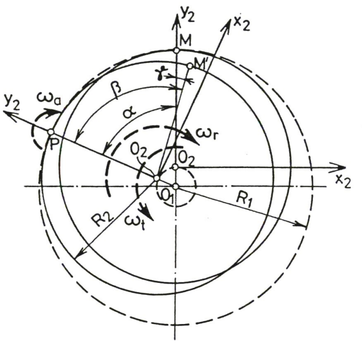
$$\begin{aligned} n_r &= z_1 \cdot n_a \\ n_t &= z_2 \cdot n_a \end{aligned} \qquad (5)$$

Because between PCP's geometry with cinematic rapport i=½ and i > ½ the study of cinematic is different for the models (table 1).

Tabel 1

Calculation for cinematic of progressing cavity pumps

Cinematic report	Device	Parameter	Calculus
i=1/2		Rotation frequency	$n_t = n_{rot} = z_2 \cdot n \Rightarrow$ $n_{rot} = n$
		Flow rate	$Q_p = V_p \cdot n_{rot} = V_p \cdot n$

i>1/2		Rotation frequency	$n_t = n_{rot} = z_2 \cdot n \Rightarrow$ $n_{rot2/3} = 2 \cdot n$ $n_{rot3/4} = 3 \cdot n$ $\vdots$ $n_{rot(7/8)} = 7 \cdot n$ $\vdots$
		Flow rate	$Q_{p(2/3)} = V_p \cdot n_{rot} = 2 \cdot V_p \cdot n$ $Q_{p(3/4)} = V_p \cdot n_{rot} = 3 \cdot V_p \cdot n$ $\vdots$ $Q_{p(7/8)} = V_p \cdot n_{rot} = 7 \cdot V_p \cdot n$ $\vdots$

Expression $n_t = n_{rot} = z_2 \cdot n$ shows dependence of the beginning of rotor. Thus the frequency of rotation of PCP's with i=2/3 overcomes single lobe PCP's, $Q_{p,2/3} > Q_{p,1/2}$, as it is obvious from the other equation.

Another optimization of PCP's performances is introduction of the concept reversed system.

Reversed systems are made by modification of the principle described above, so the stator is rolling on the outside surface of the rotor simultaneous with a rotation movement around his own axis O_1, fulfilling a planetary device when the outside wheel is satellite and the internal wheel is fixed central wheel.

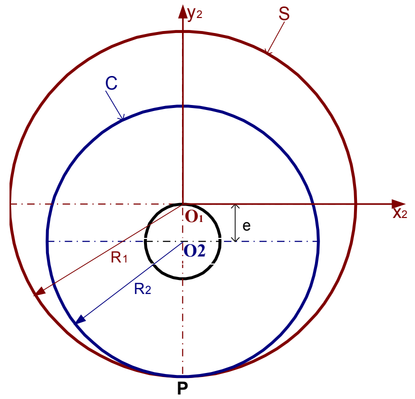


Fig. 3. Basis circles position rotor and stator

The axis O1 together with the arm port-satellite o1o2 has a rotational motion around central axis with angular speed (transport motion of stator), while the system of axis x1o1y1 (with satellite) has a rotational motion with arm port-satellite (relative movement) with angular speed.

The absolute rotational speed:

$$\omega_a = \omega_t - \omega_r \qquad (5)$$

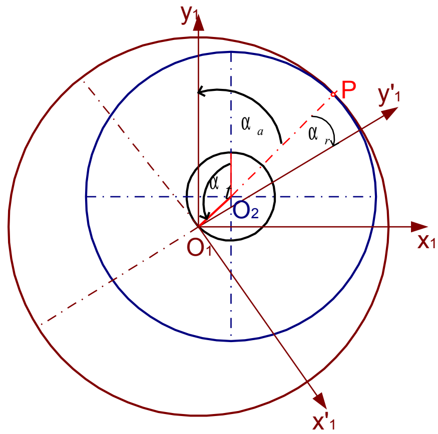


Fig. 4. Stator's position on the outside surface of the rotor after spinning with angle α_r

Because the satellite is rolling without sliding on exterior of wheel the arc PM and P'M' will be even

$$R_2 \cdot \omega_t = R_1 \cdot \omega_r \Leftrightarrow \omega_t = \frac{R_1}{R_2} \cdot \omega_t = \frac{1}{i} \cdot \omega_r \qquad (6)$$

Because

$$\begin{cases} R_1 = 2 \cdot z_1 \cdot r \\ R_2 = 2 \cdot z_2 \cdot r \end{cases}$$

and

$$z_1 = z_2 + 1 \Rightarrow \frac{R_1}{R_2} = \frac{z_1}{z_2} \qquad (7)$$

From (5), (6), (7)

$$\omega_a = \omega_r \cdot \left(\frac{1}{i} - 1\right) = \omega_r \cdot \left(\frac{z_1}{z_2} - 1\right) = \omega_r \cdot \frac{1}{z_2}$$

(8)

$$\Leftrightarrow \begin{cases} \omega_r = z_2 \cdot \omega_a \\ \omega_t = z_1 \cdot \omega_a \end{cases} \quad (9)$$

Replacing angular speed (9) with rotational frequency

$$\begin{cases} n_r = z_2 \cdot n_a \\ n_t = z_1 \cdot n_a \end{cases} \quad (10)$$

Thus the number of rotations of stator around rotor axis will be different by the number of rotations made by rotor around stator's axis.

$$\begin{aligned} n_s &= n_t = z_1 \cdot n_a = (z_2 + 1) \cdot n \\ n_r &= n_t = z_2 \cdot n \end{aligned} \quad (11)$$

With the rotation frequency of the stator can be deducted theoretical flow of fluid circulated by the pump.

$$Q_{tp} = V_p \cdot n_s = V_p \cdot z_1 \cdot n = V_p \cdot (z_2 + 1) \cdot n \quad (12)$$

Conclusions

The study of multilobe systems and introduction of the concept of reversed system are ways to optimize performances of PCP's.

To colligate the influence of cinematic on performances of PCP implies the calculus of rotation frequency of the fluid flow through both situations.

From (4), rotation frequency for classic system is given by the number of the beginnings of the rotor (z_2). From this ecuation has been calculated for different cinematic report, expressions for rotation frequency and fluid flow (tabel 1).

Similar to analisys for clasic cinematic, it was calculated formulae for rotation frequency (11) and fluid flow (12) for reversed systems.

From tabel 4, the rotation frequency of the stators around the axis of the rotor is different than the rotation frequency of the rotor around the axis of the stator $n_{st,i} > n_{r,d}$ (the rotation frequency of the systems with reversed cinematic is 1,5 times biger than the one for clasic systems).

The fluid flow for the systems with reversed cinematic (from (12)) is 1,5 times bigger than the fluid flow for direct cinematic systems.

Tabel 2

	Direct cinematic		**Reversed cinematic**
	i=1/2	i>1/2 (2/3)	i>1/2 (2/3)
n_t	$n_{rot} = n$	$n_{rot} = 2 \cdot n$	$(z_2 + 1) \cdot n = 3 \cdot n$
Q_{tp}	$Q_p = V_p \cdot n$	$Q_p = 2 \cdot V_p \cdot n$	$Q_{tp} = V_p \cdot (z_2 + 1) \cdot n = 3 \cdot V_p \cdot n$

From this point of view it is better to use PCP's with reversed cinematic especially when it is necessary to vehiculate large quantities of fluids.

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