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DOCTORAL SCHOOL OF THE FACULTY OF MECHANICAL ENGINEERING AND MECHATRONICS

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SUMMARY OF THE THESIS

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Contributions on increasing the energy performance of rotating work machine with profiled rotors

DOCTORAL COMMITTEE

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Introduction

1. The actuality of the doctoral thesis theme

The field approached through the doctoral thesis entitled *"Contributions on increasing the energy performance of rotating machine with profiled rotors*" is one of certain actuality, opportunity and importance, namely ensuring superior yields of rotating work machine, which is in line with the current efforts to implement a sustained policy of increasing machine performance. Currently, in different universities and specialized institutes in the country and abroad, constant research is carried out on the evaluation and amplification of the energy performance of the rotating work machine. The thesis is part of this line, developing a series of investigations, theoretical, numerical and experimental, regarding the use of rotating work machine for the transport of fluids, in order to reduce electricity consumption as well as fluid losses. Through its content the work aims to present a proposed model of rotating work machine that can be practically achieved in several variants.

Thus, it is studied the increase of the energy performance of the rotating work machine with profiled rotors, proposing a constructive solution for a work machine with prismatic rotating pistons of triangular section, for which the influence of geometric and functional parameters on the flow rate and drive power of the machine is studied and performing a series of experimental researches on a designed installation, designed and made specifically for solving the objectives of the thesis.

The researched phenomena are complex, their study requiring knowledge of fluid mechanics, machine organs, physics, as well as experimental research.

The doctoral thesis fits into the current researches worldwide and brings important contributions, theoretical and experimental, with implications in the fundamental field of Engineering Sciences, the doctoral field of Mechanical Engineering, with immediate applicability.

1. Content of the thesis

The work sums up a number of 148 pages, 47 tables, 108 figures and is rationally structured in 9 chapters, to which are added, at the beginning, Preface, Notations and Symbols, Abstract, Introduction and, at the end, Conclusions, Bibliography and Annexes.

The preface makes brief references regarding the theoretical and experimental research on the topic of the thesis carried out within the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment, Faculty of Mechanics and Mechatronics, University POLITEHNICA of Bucharest, under the coordinating teacher of Prof. Emeritus Dr. Ing. Nicolae BĂRAN, and thanks the people who, in one way or another, contributed to the support and moral support necessary to transport out the elaboration of the doctoral thesis.

In **the main notations and abbreviations** are written the notations of the main physical quantities encountered during the thesis, Latin letters and Greek letters, accompanied by the corresponding units of measurement, and most of the abbreviations used.

The **Abstract** briefly presents, in Romanian and English, the content of the thesis as well as the main original contributions.

In **the Introduction**, several elements of the approached issues are presented and the theoretical and practical framework of the doctoral thesis developments is specified. Thus, the importance and timeliness of efforts to increase the functional and energy performance of rotating work machine with profiled rotors is emphasized, the study objectives are set, an overview of the work is made and some observations are mentioned.

In the first part of this work, a classification of work and force machine is presented, the main types of rotating pumps are exposed: blade pumps, gear pumps, screw pumps, rotating pumps.

The following is the principle of operation and the constructive solutions of the rotating work machine with profiled rotors for the transport of liquids, the influence of the shape of the piston on the sealing between two profiled rotors, the relationship of calculation of the flow rate transported by the machine is established and the drive power of the machine is determined. An original constructive solution of a rotating volume machine is established and its advantages are listed.

A current research direction is to improve the performance of machine that circulate fluids. The optimization of the interior architecture of the work machine is a very important problem, a problem studied both in our country and abroad.

Currently, existing machine in technique evolve over time towards flow rate configurations that make them as imperfect as possible.

Both driving and working machine evolve over time in the following sense:

1. for the driving machine, the aim is to produce the maximum mechanical work transferred outside;
2. for work machine, a minimum consumption of mechanical work from the outside is pursued.

In rotating working machine with profiled rotors, the problem with the rotor architecture is the optimization of its geometry and the choice of parameters that lead to a more efficient circulation of fluids.

Minimizing the drive power of bulky machine with profiled rotors and finding a new profiled rotor architecture are key elements in the design and design of a new rotating machine.

In working machine (pumps, fans, compressors) there is a flow rate system that has a certain configuration, characterized by certain constructive dimensions and certain functional parameters.

Chapter 1. Rotating working machines for liquid transport

Chapter 1 begins with the general classification of rotating work machine, by purpose pursued, by constructive solution and by working parameters. Rotating work machine for liquid transport are classified according to the principle of operation and the mode of drive. The rotating pump with sliding vanes in the rotor shall be briefly presented. The operation of various constructive variants of gear pumps, screw pumps and loom pumps is explained. A presentation of the current state of research on rotating work machine with profiled rotors is made, a constructive and functional description of some work machine with profiled rotors provided with rotating pistons of the shape of rectangular blades, rotating pistons in the shape of a triangular prism, rotating pistons in the form of prisms with curvilinear side faces is made, highlighting some advantages of this type of work machine in relation to other rotating work machine. The chapter ends with a series of conclusions, emphasizing the usefulness of studying rotating working machine with profiled rotors in order to increase their functional and energy performance.

The work is mainly aimed at solving the following objectives:

1. Development of a new constructive solution for the rotating work machine to circulate pure liquids or with suspensions.

2. The original constructive solution must specify the shape of the contour of the rotors, i.e. computer programs must be developed to provide the x_i, y_i coordinates of the rotor contours; subsequently on a C.N.C. the rotors are made.

3. The influence of the shape of the rotors on the energy performance of the rotating work machine with profiled rotors.

4. Elaboration of calculations regarding the transported flow rate and the drive power of the volume car with profiled rotors.

5. Establishing original mathematical relationships that reveal the connection between the radius of the rotor of the rotating work machine and the height of the rotating piston.

6. The construction of the characteristic curves of the machine on the theoretical way.

7. The design of the experimental test stand and its construction.

8. Conducting experimental research with reference to chapters 3), 4) and 6) in U.P.B. laboratories.

In this work, the term "rotating work machine" will be used, which can be fan, compressor, volume pump with profiled rotors.

Considering the constructive variants of the rotating work machine studied so far, it is necessary to continue the scientific research in order to validate the theoretical researches, to improve the constructive and functional parameters that ensure superior yields, which is in line with the current efforts to implement a sustained policy of increasing the functional and energy performance of the rotating working machine.

Chapter 2. Presentation of some constructive variants of the rotating machine with two profiled rotors built so far

In this chapter, for three constructive variants of the rotating work machine with profiled rotors, the flow rate transported and the drive power are calculated according to the speed of the rotating work machine with profiled rotors, tabular and graphical and the results are commented on comparatively.

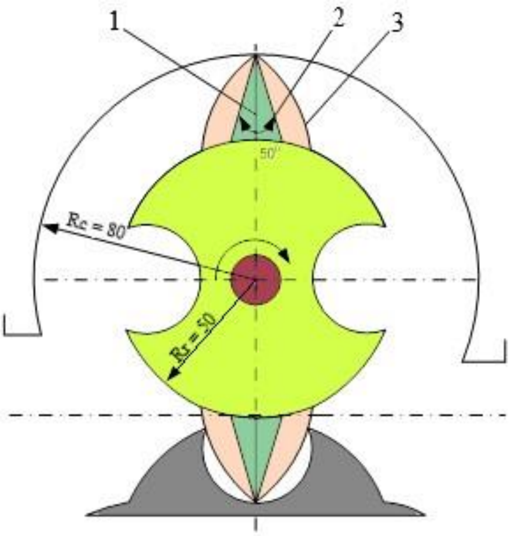

Fig. 2. 1. Rotor cu pistoane rotative
1 rectangular slide; 2 triangular profile; 3 curvilinear profile
Variant I: rotating pistons have the shape of rectangular slats;
Variant II: rotating pistons have the shape of an isosceles triangle;
Variant III: rotating pistons have the form of prisms with curvilinear lateral faces

unde R_r = 50 [mm], z = 30 [mm], R_c = 80 [mm].

The flow rate transported by the rotating machine varies depending on the geometric parameters: l – rotor length [m]; R_r – rotor radius [m]; z – piston height [m]; andaccording to functional parameters: n_r – speed of the machine [rpm].

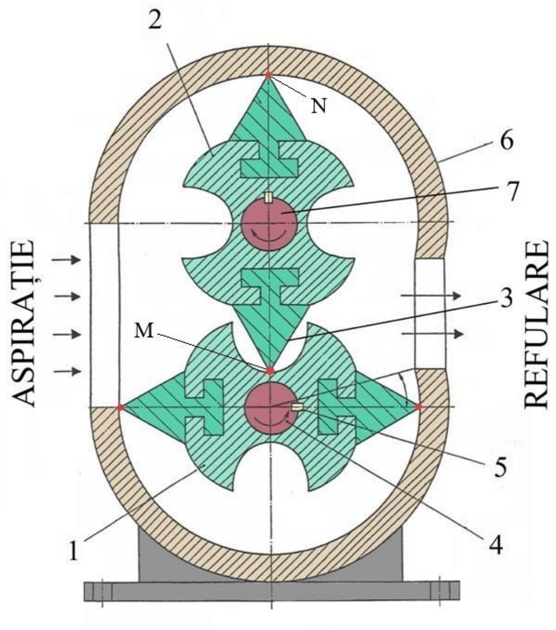

Fig. 2. 2. Section through the rotating work machine varianta II
1 – lower rotor; 2 – upper rotor; 3 – triangular piston; 4, 7 – shafts;
5 – wedge; 6 – upper housing.

During a complete rotation, the delimitation in the radial direction between the suction zone (low pressure) and the discharge area (high pressure) is ensured by the following contacts:

1. between the sharp tip of the pistons and the housings (figure 2.2);
2. between the sharp tip of the upper piston and the lower rotor (2.2).

The more perfect these contacts are (the interstitial is as small as possible) the flow rate from the high-pressure zone to the low pressure zone, the so-called "reverse" flow rate has a lower flow rate, so the machine has a higher volume efficiency.

The drive powerhas is influenced by the flow rate (i.e. by the parameters mentioned above) by the pressure increase (Δp) achieved by the rotating machine between suction and discharge, by the nature of the transported fluid. The pressure increase achieved by the rotating machine must overcome the hydrostatic load and the pressure losses that occur both on the suction circuit and on the pump discharge circuit.

In variant I (pistons in the form of rectangular slats) the flow rate transported by the rotating working machine will be the highest compared to variant III.

This high flow rate demands a higher drive power of the car: $P_I > P_{III}$ [W].

The choice of the shape of the rotors leads to an increase in the flow rate of this rotating machine with profiled rotors by increasing the volume flow rate.

The conclusions of the chapter emphasize the dependence of the flow rate transported and of the drive power on the geometric and functional parameters of the work machine, on the increase of pressure between suction and discharge, on the nature of the transported fluid, for the three variants;

it also specifies the dependence between the size of the volume yield of the machine and the flow rate "cheers".

Chapter 3. Determination of the performance ofrotating machine with pistons in the shape of a triangular prisme

In this chapter describes the constructive solution and exposes the principle of operation of the examined work machine. The initial design data, the rotor radius, R_r, the height of the piston, Z and the radius of the case, R_c, necessary for the calculation of the coordinates of the contour points of an impeller are specified. It is then proceeded to the calculation of the flow rate transported by the rotating working machine and of the theoretical drive power. Particular attention shall be paid to the calculation of the powers consumed by viscous friction between the tip of the rotating piston and the case, between the rotors and the sidewalls of the case, between the rotors and the case, depending on the speed of the rotating work machine, tabular and graphic. The power dissipated in the bearings of the machine is also calculated. Calculate the actual efficiency of the studied rotating work machine , taking into account the volume, hydraulic and mechanical yields. The characteristic curves of the rotating work machine shall be presented: the load, power and efficiency characteristics. In the conclusions section it is specified that the value of the effective efficiency of the studied rotating work machine falls within the limits, theoretical and experimental, presented in the specialized literature.

3.1. Constructive solution and principle of operation

The machine consists of two rotors (2, 7) identical to the special shape, which rotate at the same speed inside some housings (1, 5). The synchronous rotation of the rotors is ensured by two gears mounted outside the pump, on the shafts (8, 10) of the two rotors.[1]

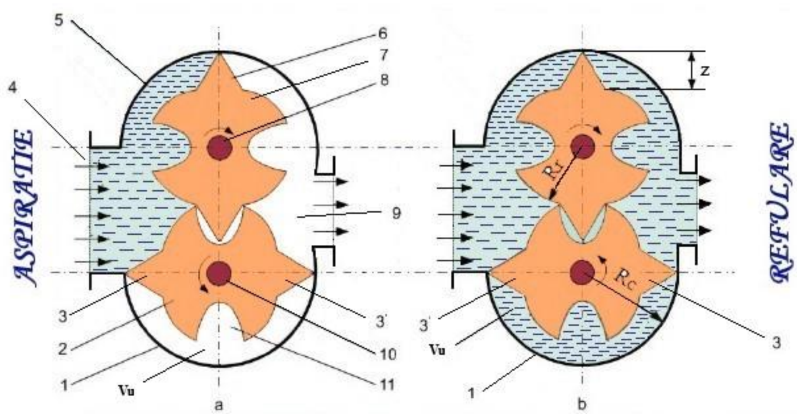

Fig. 3. 1. Position of rotors after a rotation of 180° [1]
1 – the lower casing; 2 – lower rotor; 3, 6 – rotating piston; 4 – suction chamber; 5 – upper casing; 7 – upper rotor; 8 – driven shaft; 9 – discharge chamber; 10 – driving shaft; 11 – cavity into which the piston of the upper rotor penetrates.

The fluid entering the suction chamber (4) is transported to the discharge chamber (9) by the rotating pistons (3, 6). Figure 3.1 shows the flow rate of fluid after a 180° rotation of the two rotors.

The useful volume of the transported fluid V_u, is between the two rotating pistons of the lower rotor and the lower casing (1).

Initial design data

The rotor with rotating pistons in the shape of a triangular prism has two cavities in which the pistons of the adjacent rotor penetrate. It is established first the shape of the cavity, then the shape of the contour of the rotating piston.

For the calculation of the coordinates of the rotor contour, the initial design data are:

R_r – raza rotorului [mm] R_r = 50 [mm];

z – înălţimea pistonului z = 30 [mm];

R_c – carcass radius R_c = 80 [mm].

3.2. Calculation of coordinates (xi, yi) that define the contour of a rotor

The method of calculating the x_i and y_i coordinates that define the contour of a quarter rotor is detailed, taking into account the equations the ce parameters of the movement of the peak of the piston of the lower rotor inside the upper rotor cavity and the use of a corresponding Excel program. The coordinates of the points of the cavity, of the points situated on a circle of radius R_r and of the points on one side of the triangle in the section of the rotating piston allow the tracing of a quarter of the profile of a profiled rotor, in *the xOy* coordinate system, and by symmetry to the *Ox* and *Oy* axes the whole contour of the rotor profile is obtained.

3.3. Calculation of the flow rate transported by the rotating working machine

Figure 3.2 shows the sketch of a sectioni through the rotating machine with two rotors with pistons in the shape of a triangle having z = 30 [mm], R_r = 50 [mm] and R_c = 80 [mm].

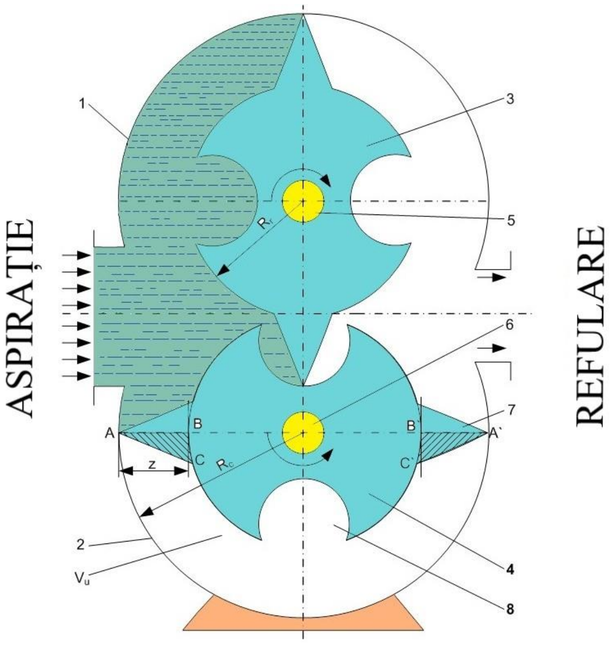

Fig. 3. 2. Cross-section through the rotating work machine
1 - the upper casing; 2 - lower casing; 3 - upper rotor; 4 - lower rotor; 5,6 - trees;
7 – triangular piston; 8 - cavityof which the piston penetrates.

The constructive s ensuresgood piston resistance and two sealing zones: between the tip of the piston and the inside of the housing and between the plunger's vrfand the cavity.

Infigure 3.2 it can be seen that the useful volume V_u is reduced by the volumes of the ABC and *A'B'C'* prisms; the two equal prisms give the volume of a piston of triangular section, with the following dimensions:

- înălţime: z = 30 [mm];
- base: b = 30 [mm];
- length: l = 50 [mm].

Nmirroringthe area of the section between the base of the prism and the impeller, the volum of the prismsi will be [30]:

$$V_p = A_{bazei} \cdot l = \frac{1}{2} \cdot b \cdot z \cdot l = \frac{1}{2} \cdot 0,03 \cdot 0,03 \cdot 0,05 ; \quad V_p = 0,0225 \cdot 10^{-3} \text{ [m}^3\text{/rot]} \tag{3.1}$$

Compared to the theoretical flow rate vehiculate by the machine, in variant I: $\dot{V} = \pi l z (z + 2R_r) \cdot \frac{n_r}{30}$ [m³/s] ,the theoretical ebit of the machine with triangular pistons is reduced by the volume of the prism V_p.

The flow rate of fluid conveyed by a rotor is

$$\dot{V}_u = \left[\pi l z \left(z + 2R_r \right) - V_p \right] \text{ [m}^3\text{/rot] .} \tag{3.2}$$

The car has two identical rotors, so the flow rate transported has the expression

$$\dot{V} = \left[\pi l z (z + 2R_r) - \frac{1}{2} b z l \right] \cdot \frac{n_r}{30} \quad \text{[m}^3\text{/s] ,} \tag{3.3}$$

$$\dot{V} = \left[\pi \cdot 0,05 \cdot 0,03 \left(0,03 + 2 \cdot 0,05 \right) - \frac{1}{2} \cdot 0,03 \cdot 0,03 \cdot 0,05 \right] \cdot \frac{500}{30} \tag{3.4}$$

$$\dot{V} = 0,00983 \text{ [m}^3\text{/s] = 35,388 [m}^3\text{/h] .} \tag{3.5}$$

Proceed similarly for the speeds n_r = 100, 200, 300 and 400 [rpm].

Tabelul nr. 3. 1. Theoretical flow rate values depending on the speed of the car

n_r [rpm]	100	200	300	400	500
$\dot{V}$ [m³/s]	0,001966	0,003932	0,005898	0,007864	0,00983
$\dot{V}$ [m³/h]	7,0776	14,1552	21,2328	28,3104	35,388

3.4. Calculation of the theoretical drive power

The theoretical drive power of the machine is obtained with the relation:

$$P = \dot{V} \cdot \Delta p \text{ [W],} \tag{3.6}$$

where Δp – pressure increase [N/m^2], $\Delta p = \rho g H$ [N/m^2];

H – pumping height [m];

ρ_l – the density of the transported fluid [kg/m^3].

For the speed of 500 [rpm] the flow rate (3.25) and the pressure increase (2.9) are replaced and the result

$$P_H = 0,00983 \cdot 0,3924 \cdot 10^5 = 385,729 \text{ [W]}. \quad (3.7)$$

Tabelul nr. 3. 2. Theoretical drive power values for different machine speeds

n_r **[rpm]**	**100**	**200**	**300**	**400**	**500**
P_H **[W]**	77,145	154,291	231,437	308,583	385,729

Itis observed that the strength of the trainhas is influenced by the flow rate and the increase in pressure Δp achieved by the pompa between suction and discharge. The pressure increase achieved by the pump must overcome the hydrostatic load and the pressure losses that occur both on the suction circuit and on the pump discharge circuit.

3.5. Calculation of the actual efficiency of the rotating work machine

The actual efficiency of a rotating machine η_{ef} is calculated with the relation (3. 8):

$$\eta_{ef} = \eta_v \cdot \eta_h \cdot \eta_m = \eta_i \cdot \eta_m \quad (3.8)$$

in which - the volume yield; η_v

η_h - hydraulic efficiency;

η_m - mechanical efficiency,

η_i - the internal yield.

As a guide, in rotating machine, the volume efficiency has values ranging from . [η_v $0,90...0,98$ 13]

The volume yield is the ratio between the actual flow rate and the theoretical flow rate:

$$\eta_v = \frac{\dot{V}_r}{\dot{V}_t} \quad (3.9)$$

The actual flow rate is lower than the theoretical flow rate due to the increase in bulk losses through leaks, "reverse" flow rate.

For the same pressure value, the volume yield is higher at large-sized pumps, since the volume losses increase more slowly than the increase in flow rate. In low-flow rate pumps, achieving high volume efficiency involves processing with high technological precision.

The hydraic efficiency is expressed as the ratio between the useful work L_u and the hydraulic work L_h for the movement of the liquid at height H.

$$\eta_h = \frac{L_u}{L_h} = \frac{H}{H + h_r} \quad (3.10)$$

where h_r hydraulic load loss

$$L_u = \dot{V}_t \rho g H \tag{3.11}$$

The mechanical efficiency of the rotating work machine is the ratio between the internal work L_i and the work of the mechanical work consumed by the machine L_c

$$\eta_m = \frac{L_i}{L_c} . \tag{3.12}$$

Indicatively the mechanical efficiency of rotating machine has values between 0,75... 0.95 η_m [13].

The internal mechanical work L_i necessary to pump the theoretical flow rate of liquid $\dot{V}_t$ at height H and to overcome the hydraulic resistors is calculated with the relation

$$L_i = \dot{V}_t \rho g (H + h_{fr}) . \tag{3.13}$$

Mechanical work L_c is mechanical workconsumed by the machine to defeat frictionsin piston-cylinder bearings

$$L_c = L_i + L_{fr} , \tag{3.14}$$

and the ratio represents the internal efficiency $\eta_i = \frac{L_u}{L_i} = \frac{\dot{V}_t \rho g H}{\dot{V}_t \rho g (H + h_{fr}) t} = \eta_v \cdot \eta_h$ of the rotating work machine, and has values between 0.82... 0.96 [13].

Replacing in relation (3. 8) the internal efficiency of the rotating work machine η_i and the mechanical efficiency , the result η_m

$\eta_i = 0,82 \div 0,99$ it is chosen; $\eta_i = 0,85$

$\eta_m = 0,75 \div 0,95$ choose . $\eta_m = 0,9$

The actual yield is

$$\eta_{ef} = \frac{L_u}{L_i} \cdot \frac{L_i}{L_c} = \frac{L_u}{L_c} \tag{3.15}$$

$$\eta_{ef} = \eta_i \cdot \eta_m = 0,85 \cdot 0,9 = 0,765 \tag{3.16}$$

This value falls within the limits indicated in the literature [13] $\eta_{ef} = 0,5 \div 0,8$.

3.6. Presentation of the characteristic curves of the rotating volume machine

The relationships that determine the performance of a machine at different operating modes, different from the calculation regimes (nominal) are called the characteristics of that machine.

Relationships can be analytical, graphic and are determined teoretically or experimentally.

Following theoretical research for the rotating work machine with profiled rotors, with rotor radius R_r = 50 [mm], the height of the rotating piston z = 30 [mm] and the radius of the housing R_c = 80 [mm] the following characteristics have been determined:

1. Characteristic of pregnancy $\dot{V} = f(n_r)$;
2. Power characteristic $P = f(n_r)$;
3. Yield characteristic $\eta_e = f(p_l)$;

where n_r = 100...500 [rpm].

1. Pregnancy feature $\dot{V} = f(n_r)$.

In the relationship of calculating the flow rate, the values of the quantities corresponding to the built model for which the experimental researches are also carried out are replaced, and on the basis of the values resulting in Table 3. 1 plotted in Figure 3.3 the load characteristic; the theoretic flow rate according to the speed of the rotating work machine.

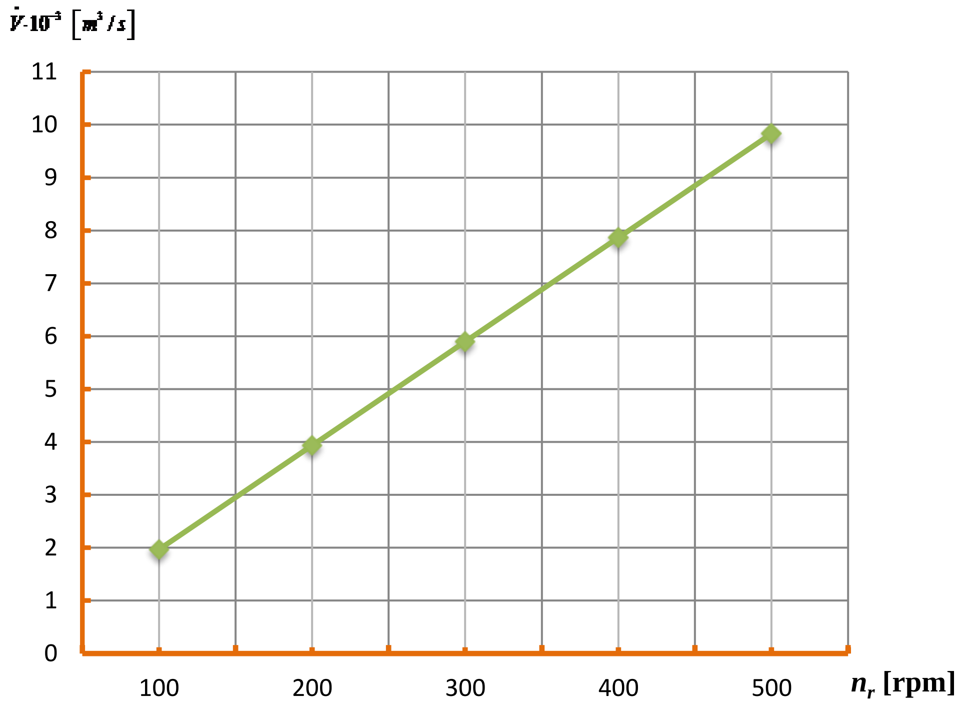

Fig. 3. 3. Graphical representation of the load characteristic

1. Power feature: $P = f(n_r)$

Based on the data resulting in Table 3. 2, figure 3.4 graphically constructed the function of the theoretical drive power according to the speed, representing the power characteristic of $P = f(n_r)$ the rotating working machine.

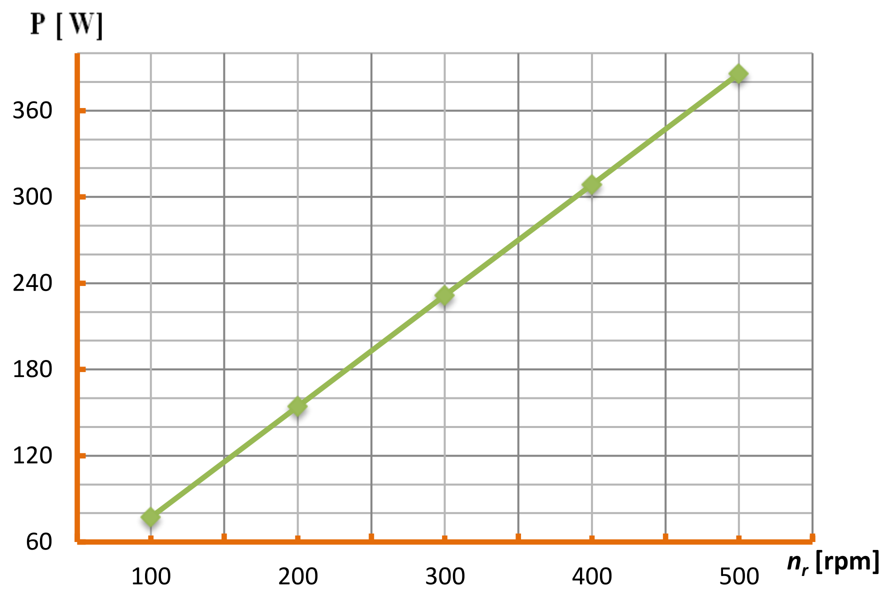

Fig. 3. 3. Graphical representation of the power feature

1. Yield feature: $\eta_e = f(p_l)$.

For the efficiency characteristic **generally represented** in Figure 3.15, it is noted that the pump efficiency value increases until a limit value is reached and subsequently decreases as a result of a decrease in volume and mechanical efficiency η_{ef} $p_{\lim}$ η_v η_m.

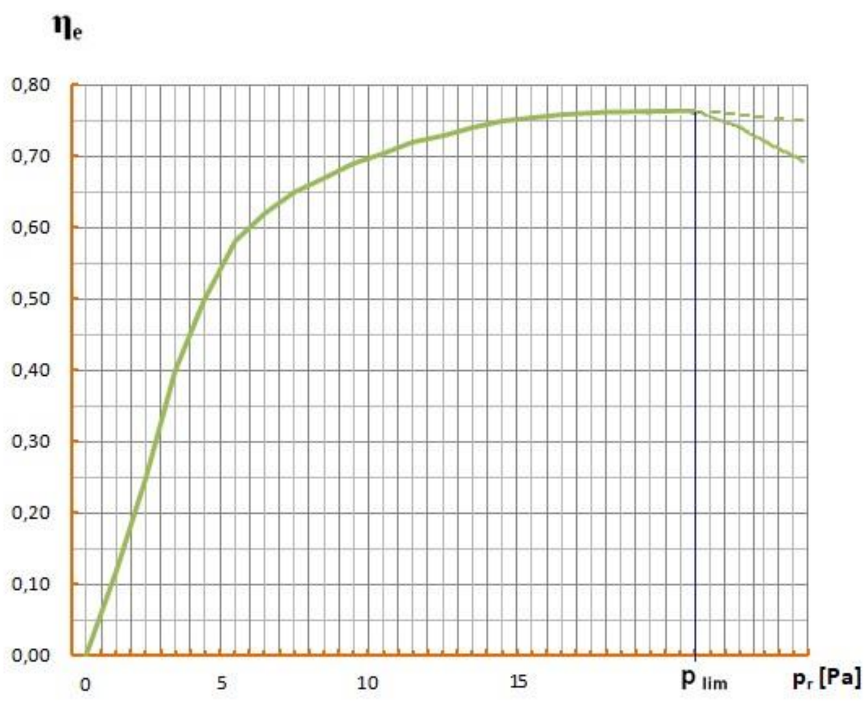

Fig. 3. 4. Graphical representation of the yield feature

The value of the effective efficiency of the rotating machine falls within the limits presented in the specialized literature [2].

Chapter 4. Presenting an original idea for changing the architecture of profiled rotors

In this chapter, a new shape of the rotor contour is mathematically established at which the profiled rotor rotors have an original contour, namely the height of the rotating piston *z* has values close to the rotor radius R_r. Based on the coordinates, a constructive solution of the model of the rotating working machine with two rotors of the original shape was obtained.

Compared to the constructive variant shown in chapter 3, the rotor radius and the height of the piston $R_r z$ are changed. The rotor has a radius = 40 [mm], it is provided with two rotating pistons with a height of 38 [mm] and R_r two cavities in which the pistons of the adjacent rotor penetrate.

Starting from the relationship of the theoretical drive power of the rotating machine (2.8), it is obtained

$$P = \pi \cdot l \cdot z \cdot (z + 2R_r) \cdot \frac{n_r}{30} \cdot \Delta p \quad [W] \tag{4.1}$$

where $l = k \cdot z$, $k = 1, 2, 3 \ldots n$

$$P = \left(\pi \cdot k \cdot z^3 + \pi \cdot k \cdot z \cdot 2R_r\right) \frac{n_r}{30} \cdot \Delta p \quad [W]\,. \tag{4.2}$$

It is noted that the size "*z*" is the determining factor in the value of *P*. Astlef, se first establishes the shape of the cavity, then the contour shape of the rotating piston.

The contour of the rotor profile is symmetrical to the *Ox* and *Oy* axes, as a result it is sufficient to draw the contour for a quarter of the dial and then by symmetry to *Oy*, half of the rotor is obtained and subsequently by symmetry to *the ox* is obtainede the entire u r accountof the rotor.

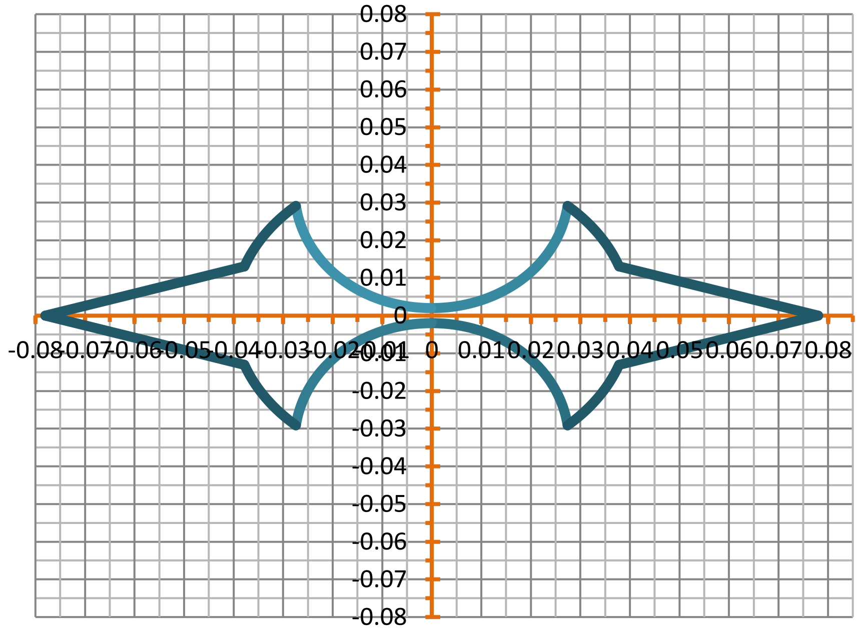

Fig. 4. 1. Profile contour of the rotor provided with pistons in the shape of a triangular prism

Possessing this mathematical model of calculation that specifiesthe shape of the rotor contour, we proceeded to the elaboration of a technology for the execution of the rotor [3], [4], later to its practical realization.

The author of this doctoral thesis made this rotor with the help of a 3D printer in order to demonstrate the operation of this proposed model of rotating work machine with two rotors of the original shape.

In Figure 4. 2 is presented theconstructive number of the model of the rotating machine with two rotors of original shape.

It has the following peculiarities:

1. arborele for each rotor does not penetrate inside the rotor, so the height of the rotating piston *z* must have a value as close as possible to the radius of the rotot R_r [5] ;
2. athe rbores drive the lower rotor by means of a flange fixed with screws to the rotor; the flange rotates inside the sidewall (10) of the housing (figure 4.2.b);

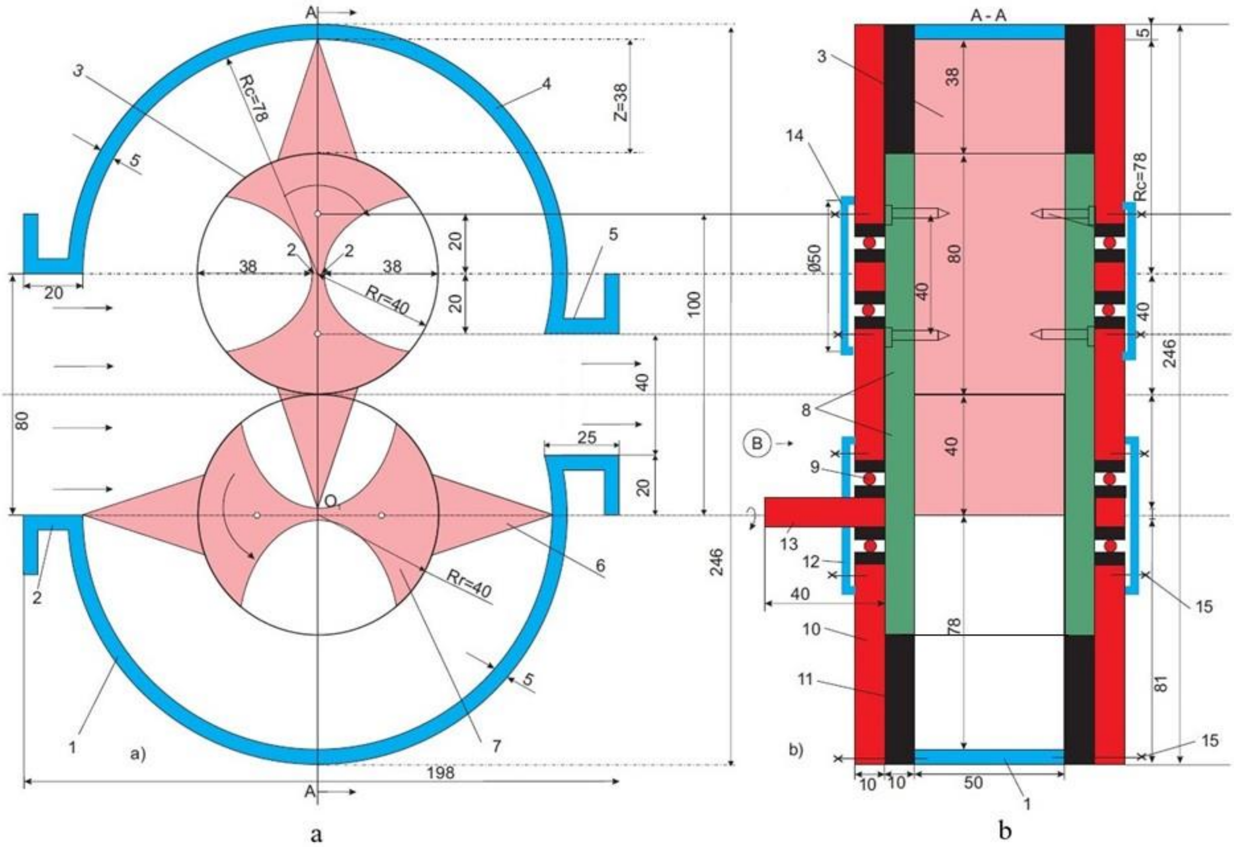

Fig. 4. 2. Cross-section (a) and longitudinal section (b) through the rotating machine [5]
a: 1 – lower carcase; 2 – fluid suction connection; 3 – upper rotor;
4 - upper casing; 5 – fluid discharge connection; 6 – rotating piston; 7 – lower rotor;
b: 8 – gears; 9 – bearings; 10 - side (left) wall of the housing;
11 – intermediate wall; 12 – bearing cover; 13 – driver shaft;
14 – sealing caps; 15 – clamping screws.

Previous research in the field of rotating machine [6], [7] continues with this proposed new model at which the height of the rotating piston *z* must have a value as close as possible to the radius of the R *r* rotating piston.

The result obtained mathematically $z = R_c$ which leads to an increase in the flow rate of the volume pump was intended to be verified to be functional. Thus, a plastic demonstration model with the main data $z = 38$ [mm], $R_r = 40$ [mm], $R_c = 78$ [mm] was designed.

Figure 4.3 also provides thesqueak of the demonstrative model, a constructive solution that allows z to have values close to R_r. Itis noted that in order to prevent the "reverse flow rate" a central portion of the rotor of 4 [mm] thickness [8] was left.

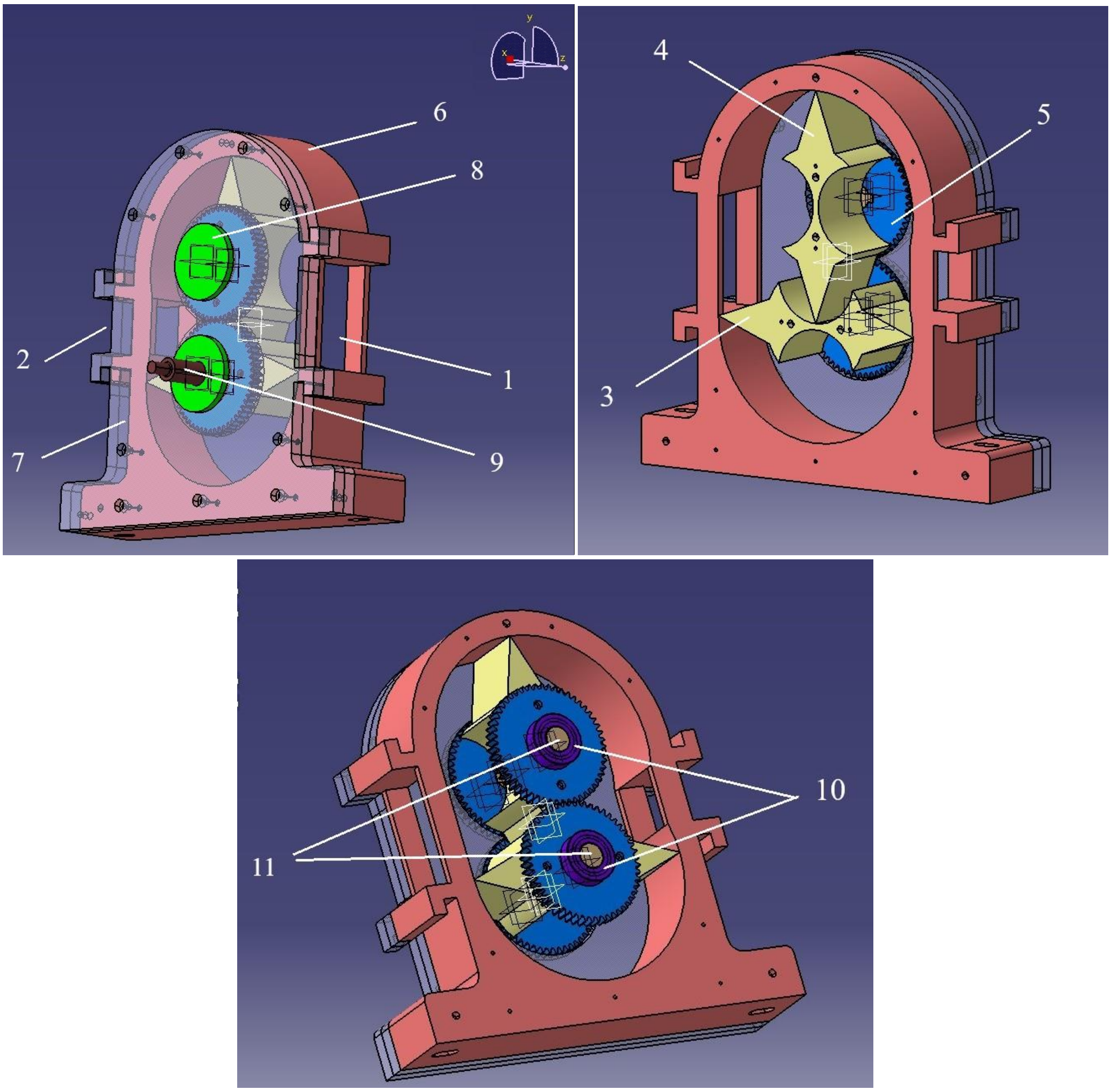

Fig. 4. 3. Axonometric view of the demonstrative model of rotating work machine with profiled rotors
1– suction chamber; 2 – discharge chamber; 3 – lower rotor; 4 – upper rotor;
5 – gears; 6 – rotating work machine casing; 7 – side walls; 8 – sealing caps;
9 – driving shaft; 10 – bearings; 11 – driven shafts.

The demonstration model of the rotating work machine was made at the scale of 1:1.

After the design, for the realization of the intermediate walls and sealing covers, transparent plexiglass plates with a thickness of 10 [mm] were purchased, which were processed on the basis of the execution drawings, on a numerical control center (C.N.C) [9].

The other parts of the demonstration model were made using a 3D printer.

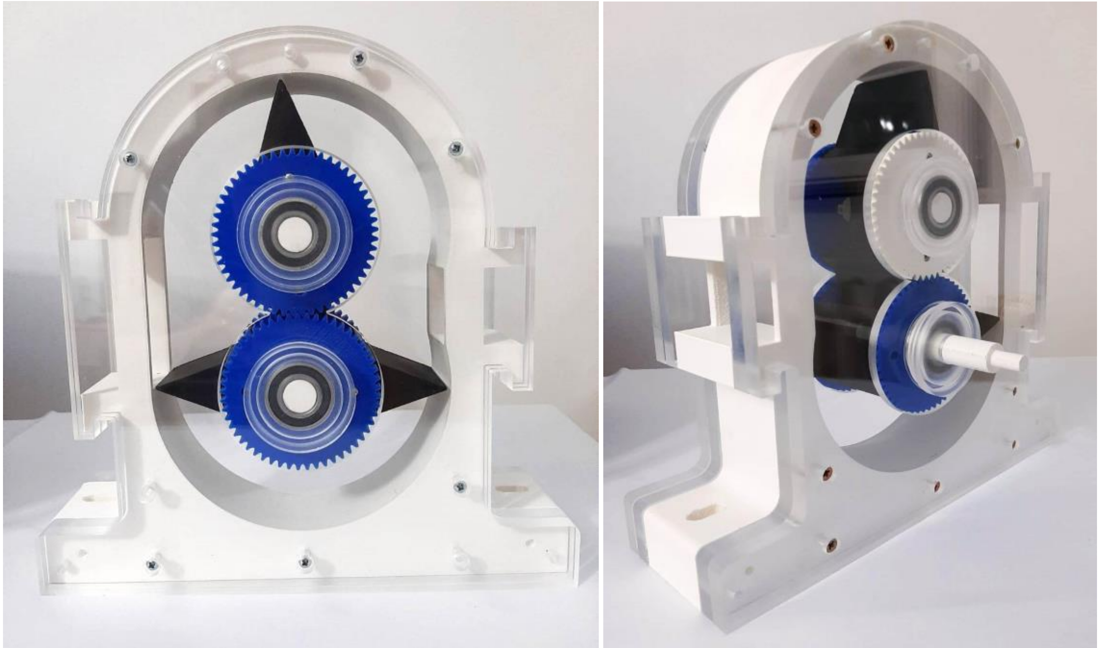

Fig. 4.4. Demonstration model of newly designed rotating machine with profile rotors[10]

Figure 4.5 shows the test bench of the demonstration model with a view to putting into service and monitoring its behaviour in operation.

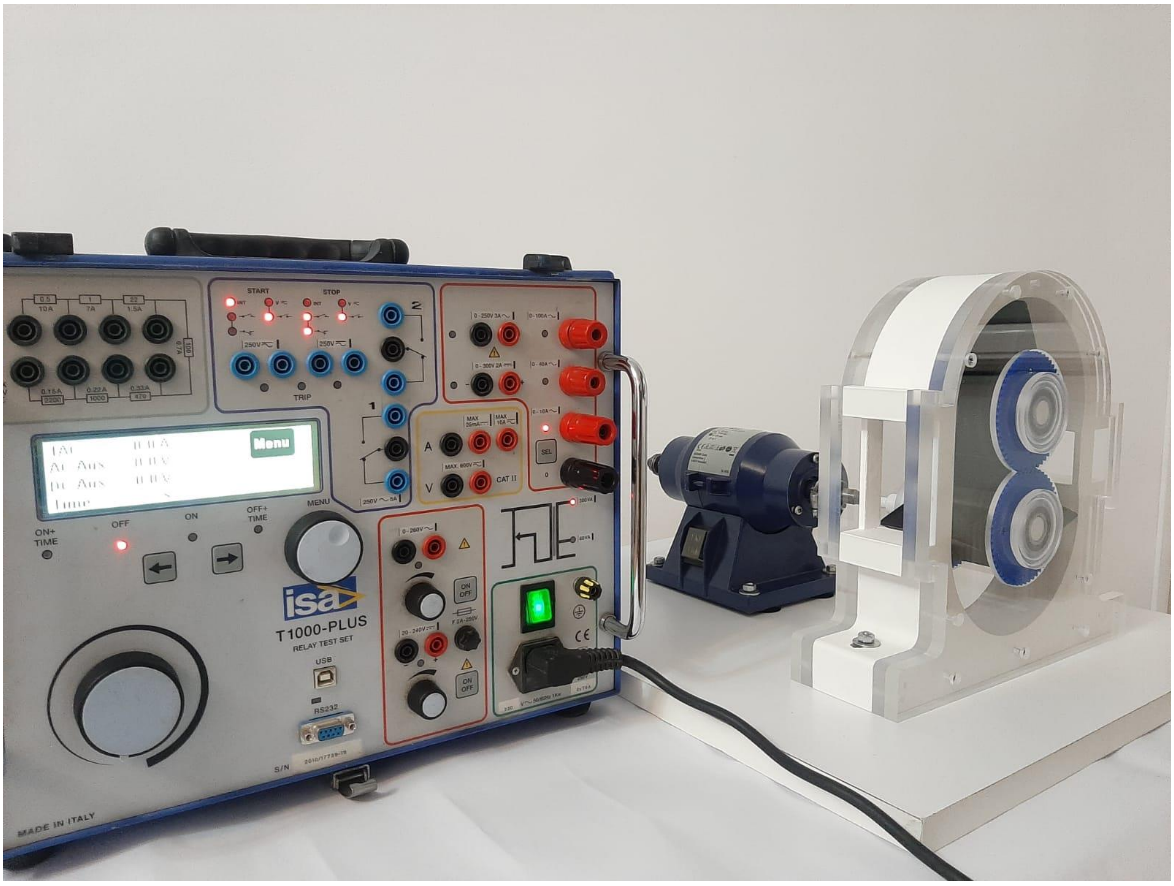

Fig. 4.5. Overview of the test bench during operation

The demonstration model of the rotating work machine with profiled rotors is driven by an electric motor; the assemblyl motor electric + rotating machine is mounted on a base plate. An ISA

T1000 PLUS automatic single-phase test kit [11], [12] was used to vary the speed of the electric motor.

The mathematical model for calculating the coordinates of the contour of the rotor profile has a general character; it can be modified for other dimensions of the rotor being necessary to specify only the values z and ; R_c

During experimental research, a video recording was made for the demonstration model demonstrating the operation of this original solution; the video recording will be presented on the occasion of the public presentation of the work.

Chapter 5. A new constructive solution for the working machine with prismatic rotating pistons of triangular section

This chapter sets out the constructive solution of the new type of rotating machine with two profiled rotors for which the rotor radius R_r has remained equal to 50 [mm] and the height of the rotating piston z has been increased to 48 [mm]; the coordinates of the rotor contour and the coordinates of the rotating piston are calculated; constructive details of the components of the machine are given.

Based on the coordinates obtained, the profile of the rotating piston was graphically built in Excel, and then the data were entered in the Catia Dassault System program, for modeling the rotor part.

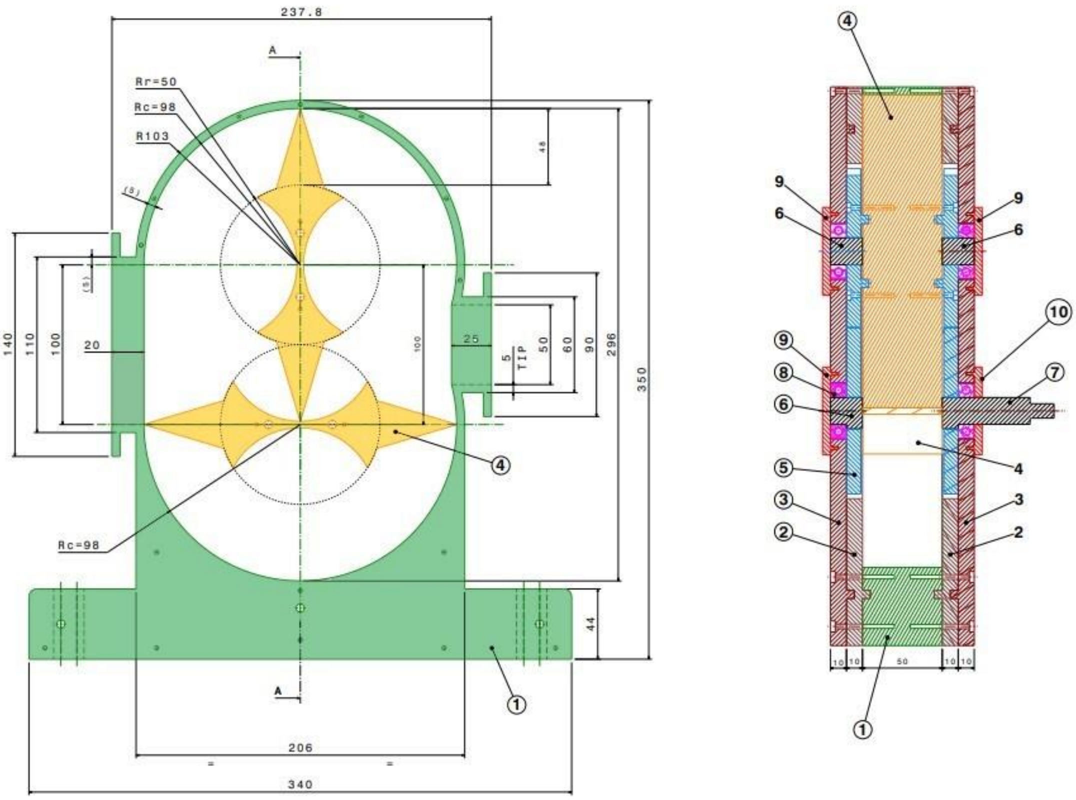

Fig. 5. 1. Cross section (a) and longitudinal section (b) through rotating machine
1 - oval casing; 2 - intermediate wall; 3 - left side wall; 4 - rotating piston; 5 - gears;
6 - driven shaft; 7 - leading shaft; 8 - ball bearing; 9 - bearing cover;
10 - driver shaft bearing cover.

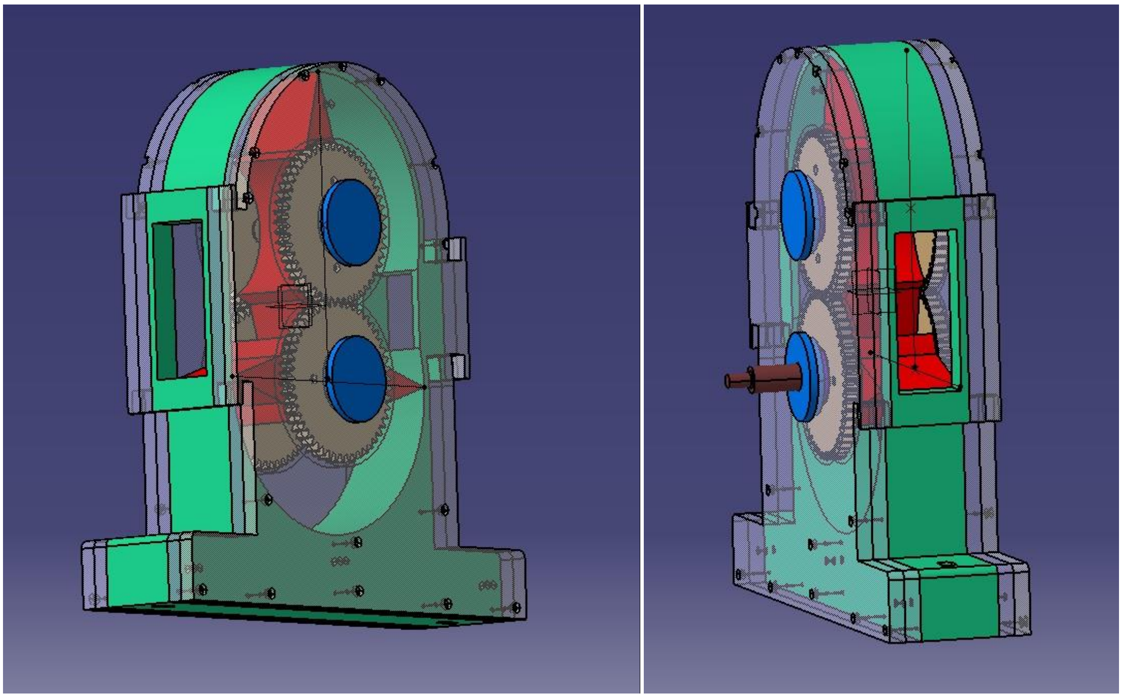

Fig. 5. 2 . Axonometric view of the new type of rotating machine with rotors of original shape

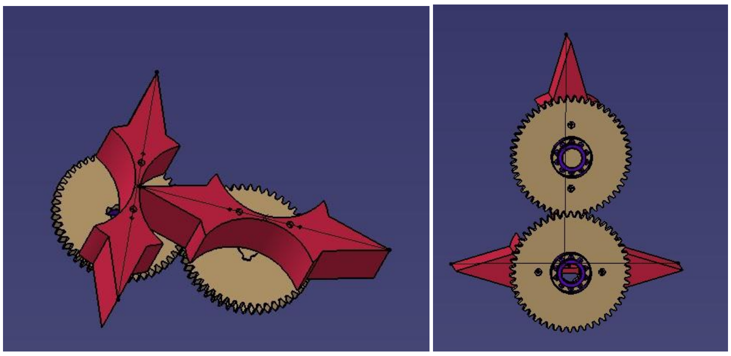

Fig. 5. 3. Side view of the rotors and gears of the new type of rotating machine with rotors of the original shape

Subsequently, the transported volume flow rates and the theoretical drive powers are calculated in order to determine the actual r andament of the rotating machine

The refurbishment of the pumping stations in the field of land improvements, respectively the increase of the energy performance of the pumps, in general and of the rotating work machine with profiled rotors, in particular, are the problems most often encountered by the Organizations of Water Users for Irrigation, in order to reduce energy and water consumption. This is necessary to improve the efficiency of operation.

In this chapter it is revealed a solution of rotating work machine that has the following advantages:

1. by increasing the height of the piston, the usable volume is increased, as a result, the flow rate of fluid transported by the rotating working machine is increased;
2. keeping the speed of the rotating work machine constant, compared to the constructive variant of the rotating work machine with rotating pistons in the form of prisms with the curvilinear side faces., the flow rate of fluid transported increases;

3. la speed increase, the efficiency of the rotating machine will increase to a certain value, then it will begin to decrease; this is because, when increasing the speed, the flow rate increases, so the pressure losses on the hydraulic circuit increase;
4. the actual andament of the rotating machine is influenced by the nature of the fluid transported, by viscosity;
5. The theoretically calculated value of the yield falls within the range of values given in the literature [13], from which it appears that the architecture of the rotating work machine influences the efficiency of the pumping aggregate.

Chapter 6. Influence of geometric and functional parameters on the flow rate and drive power of the rotating work machine

This chapter shows the influence of constructive parameters (z – height of rotating piston, R_r – rotor radius, l – rotor length) and functional (n_r – the icicles of the rotating work machine) on the flow rate transported by the rotating work machine and on the drive power.

Thus, a single constructive variant with which the experimental researches are carried out are further analyzed, namely the constructive variant analyzed in chapter 3. - the rotating working machine with rotating pistons of the shape of a triangular prism for which R_r = 0.05 [m], z = 0.03 [m], R_c = 0.08 [m] .

It is thusdemonstrated the d ebit transported by the rotating work machine increases linearly with the speed of the machine, andthe drive p uterea increases linearly with the speed of the rotating machine and with the increase of total pressure achieved by the rotating work machine. The increase in the speed of the machine is limited by the fact that the fluid speed in the suction connection of the rotating work machine should not exceed about. 1 [m/s].

Previously, in chapter 3, the calculation relationships for

1. the volume flow rate transported by the car

$$\dot{V}_u = \left[\pi l z\left(z+2R_r\right)-V_p\right]\cdot\frac{n_r}{30}\ \text{[m}^3\text{/s]}, \tag{6.1}$$

1. theoretical drive power of the machine

$$P=\dot{V}\cdot\Delta p=\left[\pi l z\left(z+2R_r\right)-V_p\right]\cdot\frac{n_r}{30}\cdot\Delta p\ \text{[W]}. \tag{6.2}$$

The three elements (rotor radius, piston height and housing radius) are analyzed together because they are linked by the relation

$$R_c = R_r + z \quad \text{[m]}. \tag{6.3}$$

For values close to those used in the laboratory, replacing in the flow rate calculation relationship, for different values of l, the data necessary to draw up the linear function graphically $\dot{V} = f(l)$ represented in figure 6.1 are obtained.

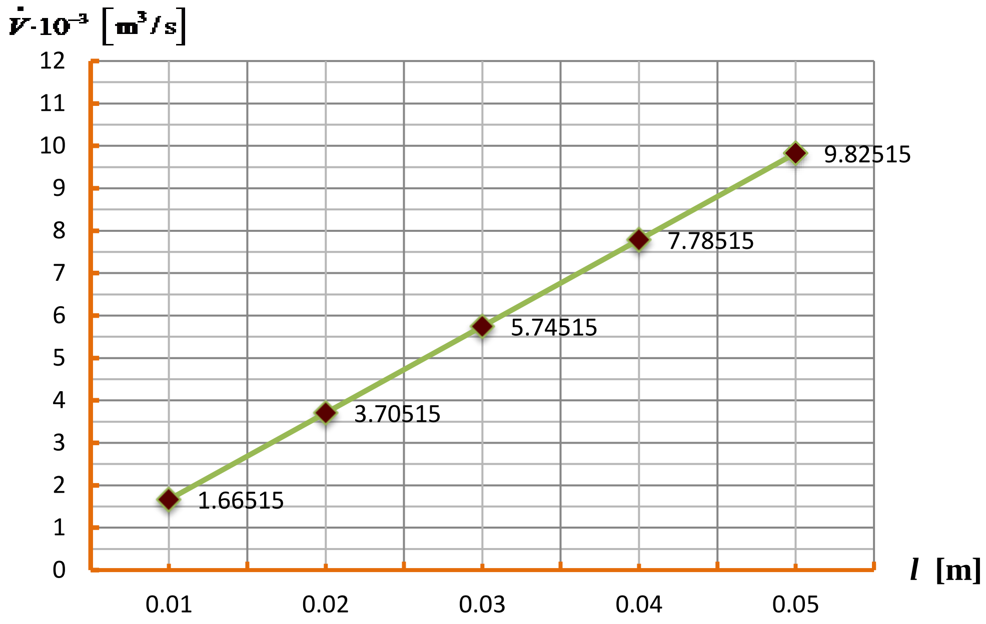

Fig. 6. 1. Graphical representation of the flow rate according to the length of the rotor

For the representation of the graph of the function $\dot{V} = f(R_r)$ in Figure 6. 2. se know $R_r = 0,05$ [m]; [m]; [m]. $z = 0,03$ $l = 0,05$

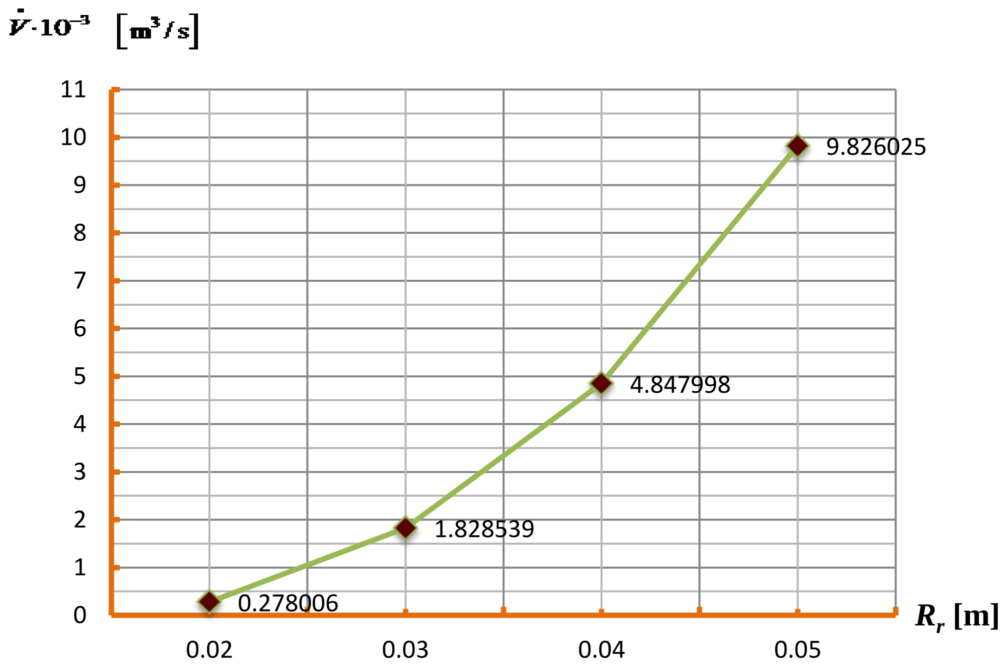

Fig. 6. 2. Graphical representation of flow rate variation depending on rotor radius

The influence of piston *height z* on flow rate and power [14], [15], [16] is analyzed.

Trebuie stated that z in relation to R_r or R_c cannot be chosen anyway, adithat it cannot have any value. Values are given for z and results in the graph of its function $\dot{V} = f(z)$ in the range z = 0.....0,05 [m].

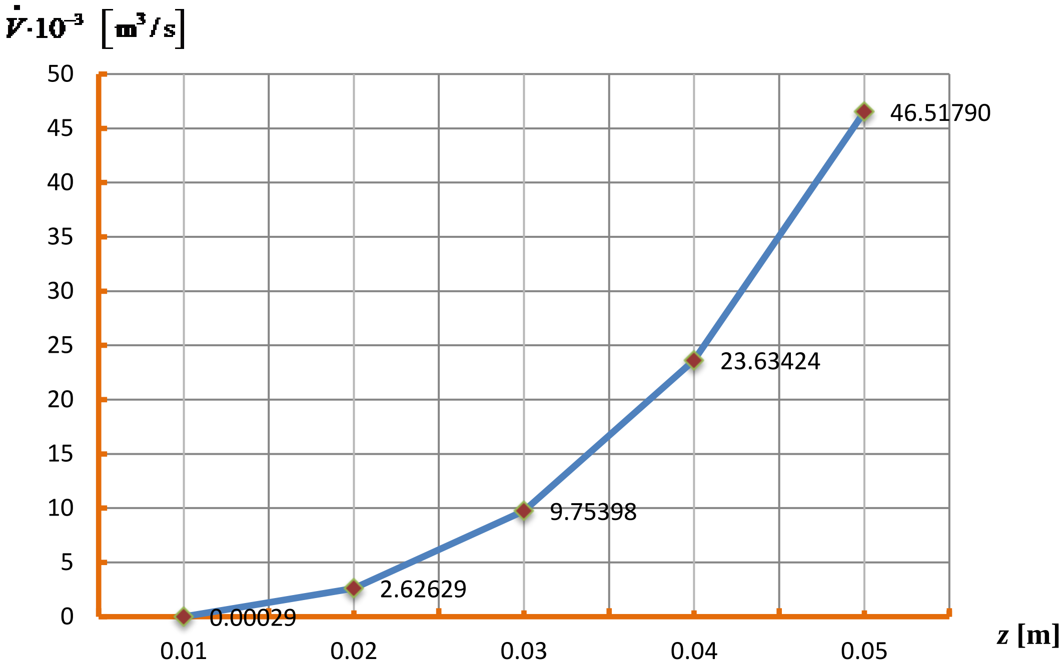

Fig. 6. 3. Graphical representation of the flow rate according to the height of the piston

From Figure 6. 3. Note the importance of the height of the piston *z* on the volume flow ratetransported by the rotating work machine with profiled rotors; the higher the height of the piston increases, the higher the volume flow rate transported.

Next, the equation (6.1) is resumed, which specifies the flow rate conveyed by the rotating working machine, the rotor radius R_r = 0,05... 0,088 [m]; height of rotating piston *z* = 0,01.......0,048 [m] and speed n_r = 100, 200, 300, 400, 500 [rpm] and the flow rate values shown in Table 6.1 plotted in Figure 6.4 are obtained.

The maximum value of the height of the rotating piston is thus determined mathematically, which leads to the maximum flow rate of fluid that can be given by the machine for a given speed.

Tabelul nr. 6. 1. Flow rate values depending on the speed, height of piston and rotor radius

Variant No.	I	II	III	IV	V
z [m]	0,01	0,02	0,03	0,04	0,048
R_r [m]	0,088	0,078	0,068	0,058	0,05
R_c [m]	0,098	0,098	0,098	0,098	0,098
$\dot{V}\cdot 10^{-3}$ [m³/s]	0,8984	1,7671	2,5312	3,1906	3,6428
	1,7968	3,5343	5,0624	6,3812	7,2855
	2,6952	5,3014	7,5936	9,5718	10,9283
	3,5936	7,0685	10,1248	12,7624	14,5710
	4,4920	8,8357	12,6560	15,9530	18,2138

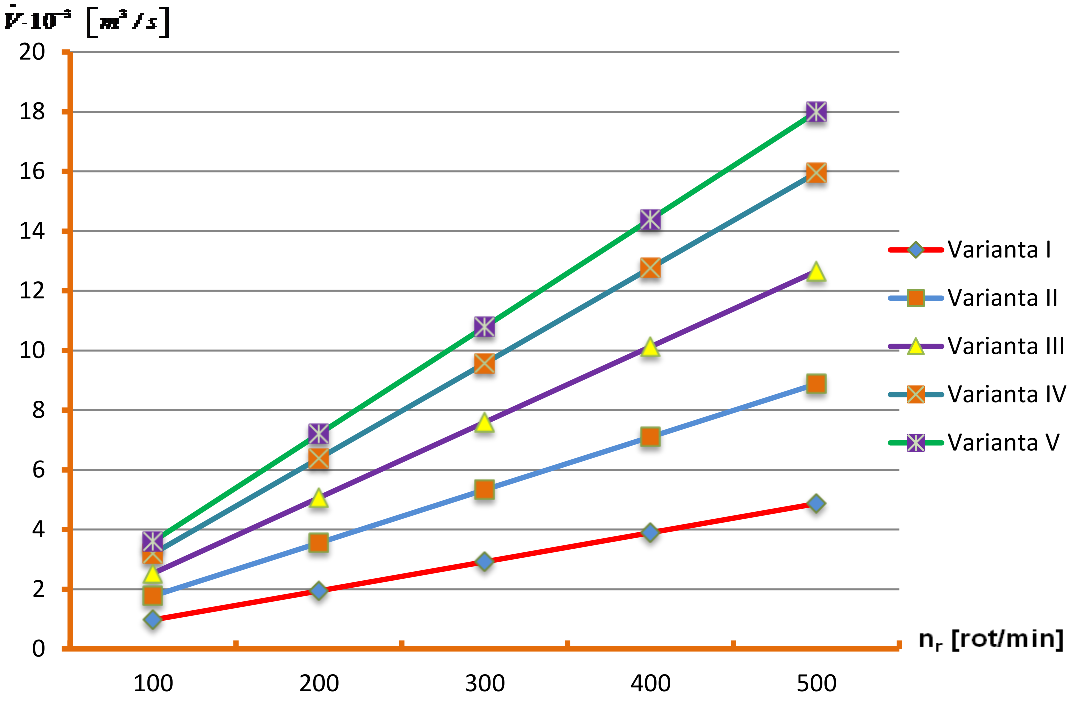

Fig. 6. 4. Graphical representation of the flow rate according to the speed, height of the piston and rotor radius

Figure 6.4 shows that the maximum flow rate is obtained when the height of the rotating piston z is as close as possible to the radius of the rotot R_r and the flow rate increases with the speed of the rotating working machine n_r.

Previous experimental research [17], [18], [19] confirms the correctness of the calculations made.

In order to analyze the influence of the piston height on the drive power, the relationship of calculation of the drive power of the rotating work machine (6.2) is resumed $P = \dot{V} \cdot \Delta p$, for Δp = ct results

$$P = ct\dot{V} \tag{6.4}$$

therefore, the parameters that influence the volume flow rate $\dot{V}$ influence in the same sense the theoretical drive power of the rotating working machine P.

$$P = \left(375{,}142 \cdot z^3 - 0{,}37485 \cdot 10^{-3}\right) \cdot 0{,}3924 \cdot 10^5 \qquad \text{[W]} \tag{6.5}$$

With the same values for it was $z = 0{,}01 ... 0{,}05$ graphically represented in Figure 6.5 the variation of the drive power depending on the height of the rotating piston.

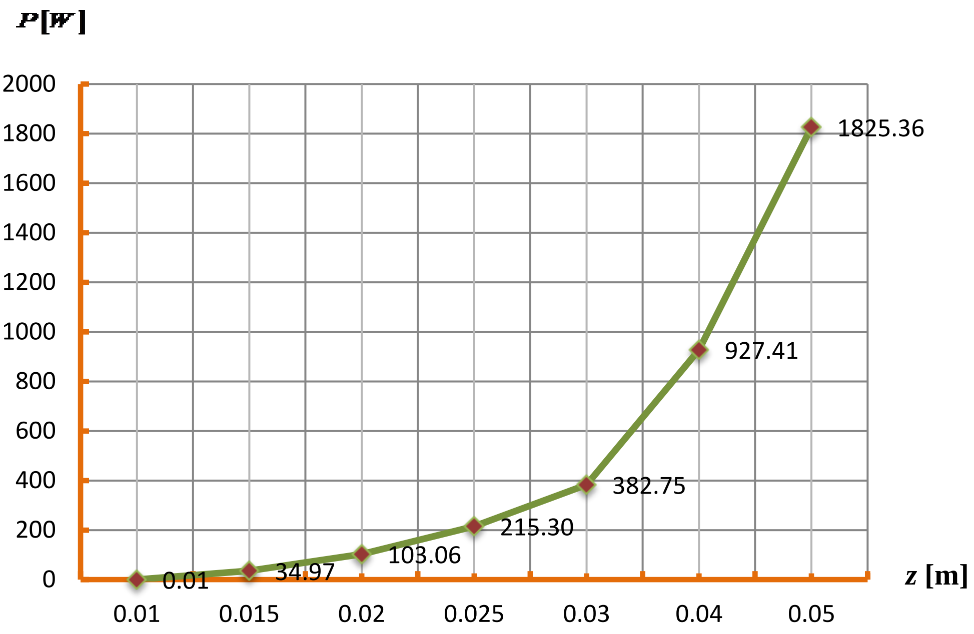

Fig. 6. 5. Graphical representation of the drive power according to the height of the rotating piston.

From Figure 6.5. it can be seen that the power required to train the machine increases exponentially with the value of z.

$$f(x) = x^n \Rightarrow P = f(z^3) \tag{6.5}$$

Depending on the execution technology available to the beneficiary, for a certain debit transported by the rotating work machine, we choose *l*, R_r and *z*.

Next, based on the data from sheet 6.2 that specifies the flow rate transported by the rotating working machine,the values of the theoretical drive power (Table 6.6) are obtained, values that vary depending on the radius of the rotor and the height of the piston.

Tabelul nr. 6.2. Flow rate values according to rotor radius and piston height

Nr. Variantă	I	II	III	IV	V
z [m]	0,01	0,02	0,03	0,04	0,048
R_r [m]	0,088	0,078	0,068	0,058	0,05
R_c [m]	0,098	0,098	0,098	0,098	0,098
P [W]	35,2532	69,3423	99,3243	125,199	142,942
	70,5064	138,685	198,649	250,398	285,884
	105,76	208,027	297,973	375,597	428,826
	141,013	277,369	397,297	500,797	571,768
	176,266	346,712	496,621	625,996	714,71

Based on the data in Table 6. 2. the variation of the drive power as a function of the height of the rotating piston was plotted in Figure 6.6.

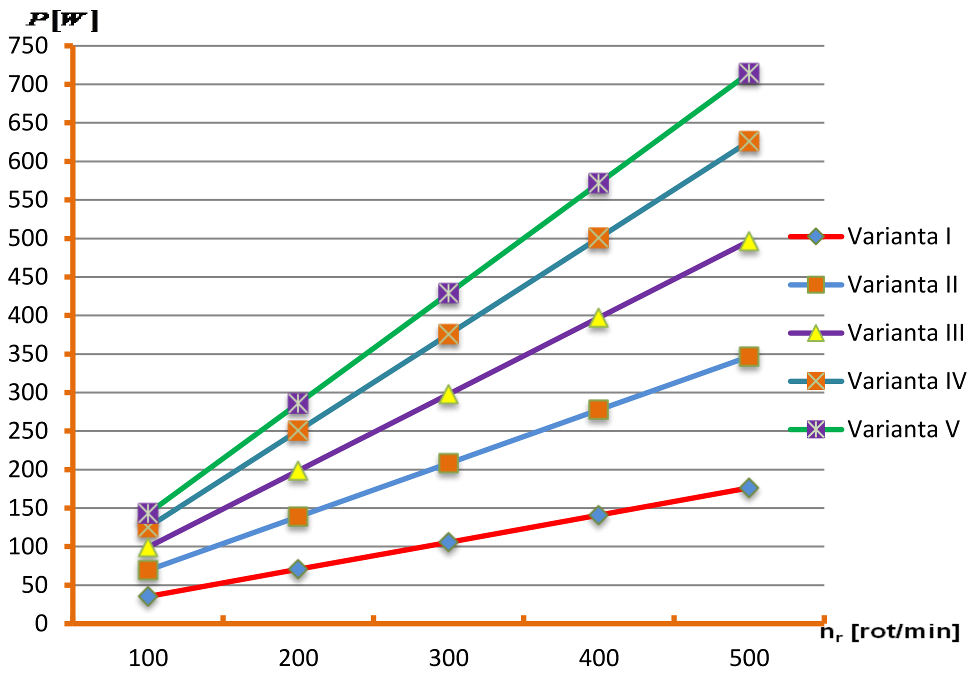

Fig. 6. 6. Graphical representation of the drive power according to the speed, height of the piston and rotor radius

Analyzing the formula of the volume flow rate transported by the rotating machine and of the drive power of the rotating machine, it is found that the volume flow rate and $\dot{V}$ *the drive power P* of the rotating work machine are influenced by two categories of parameters:

- Constructive parameters: rotor length: rotor length l [m]; rotor radius R_r [m]; rotating piston height z [m].

- Functional parameters: rotating work machine speed n_r [rpm/min]; pressure increase [N/m Δp ²].

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The speed of the *car* n_r influences both the volume flow rate transported by the car and the drive power of the car. The dependency is linear: ; $\dot{V} = f(n_r)$ $P = f(n_r)$ As the speed of the car increases, the volume flow rate and the drive power $\dot{V}$ P increases.

Thus, for two constructive variants

Variant I z = 0.03 [m],R $_r$ = 0.05 [m], R_c = 0.08 [m];

Variant II z = 0.048 [m], R_r = 0.05 [m], R_c = 0.098 [m];

the speed was varied between 100 and 500 revolutions per minute and the data from Table 6.7 representing the influence of the speed on the flow rate transported foreach constructive variant were obtained.

Tabelul nr. 6. 3. The influence of the speed on the flow rate transported for each constructive variant

n_r [rpm]		**100**	**200**	**300**	**400**	**500**
Varianta I	$\dot{V}\cdot10^{-3}$ [m³/s]	1,946	3,892	5,838	7,784	9,730
Varianta II	$\dot{V}\cdot10^{-3}$ [m³/s]	3,5978	7,1955	10,7933	14,3910	17,9888

Based on the data in Table 6.3 , the influence of speed on the flow rate for the two construction variants was graphically represented in Figure 6.7.

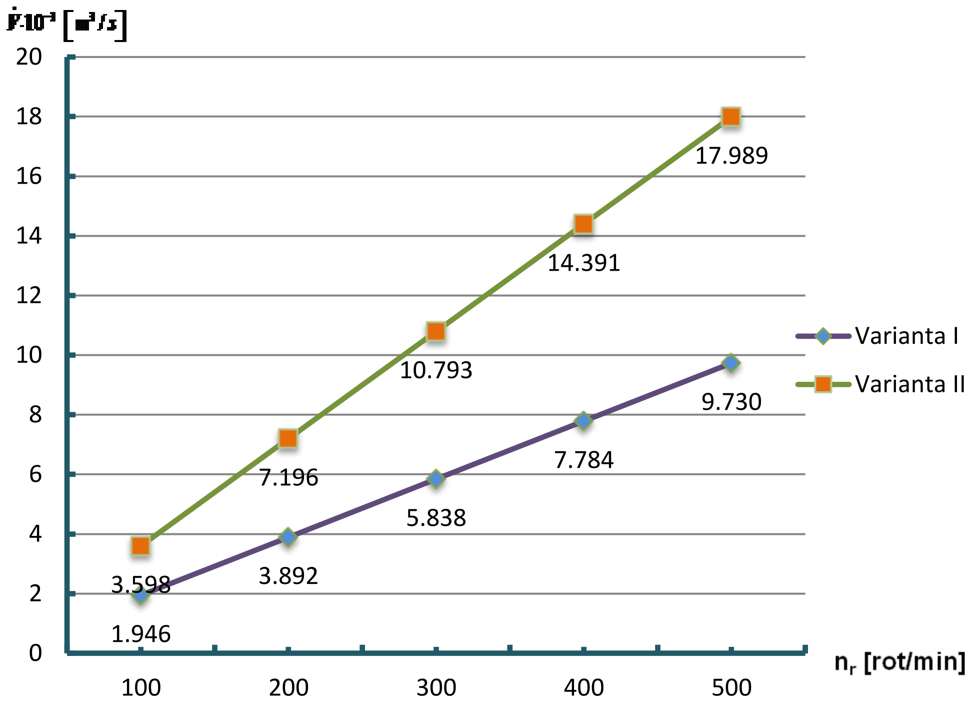

Fig. 6. 7. Graphic representation of the speed influence on the flow rate transported for the two constructive variants:

Variant I $z = 0.03$ [m],R $_r = 0.05$ [m], $R_c = 0.08$ [m];

Variant II $z = 0.048$ [m], $R_r = 0.05$ [m], $R_c = 0.098$ [m].

Figure 6.7 shows that the volume flow rate $\dot{V}$ rate increases linearly with the height of the *piston z* of the rotating work machine. At the same time, the flow rate afferent to the construction variant II is influenced by the architecture of the rotors.

Taking into account that $P = \dot{V} \cdot \Delta p$ [W], for flow rate values at $n_r = 300$ the speed [rpm/min], modifying Δp, the graph and the influence of the pressure increase on the drive power of the machine for the two constructive variants were graphically represented.

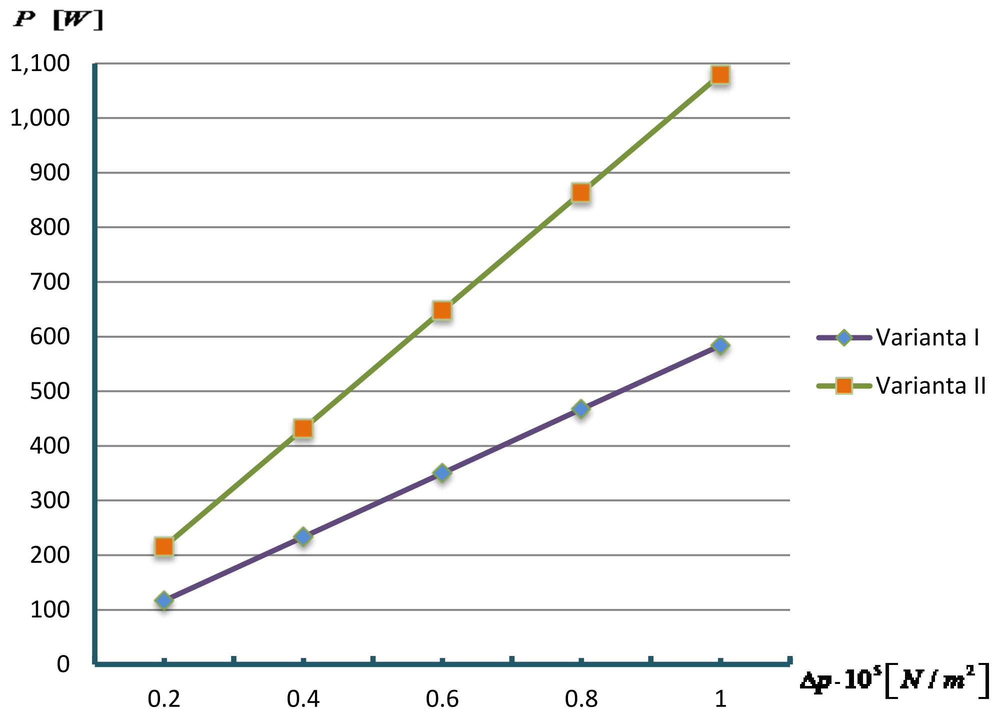

Fig. 6. 8. The graphical representation of the influence of the increase of pressure on the drive power of the work machine for the two constructive variants.
Variant I z = 0.03 [m],R $_r$ = 0.05 [m], R_c = 0.08 [m];
Variant II z = 0.048 [m], R_r = 0.05 [m], R_c = 0.098 [m].

From fig6.8 it is observed that the drive power of the rotating work machine increases similarly to the pressure increase achieved by the machine.

Compared to the piston work machine with alternating rectilinear motion used to transport the same fluid flow rate, the energy consumption is lower in the case of rotating work machine with profiled rotors, since the motor torque at shaft level is almost entirely transmitted to the transported fluid.

Rotating work machine have advantages:

1. transforms the motor moment received at the shaft, with minimal loss, in potential energypressure of the fluid [20], [21], [22];
2. ethey have an increased reliability in operation, they do not requiretrellision over a long period of time;

The two functional parameters n_r and act on the flow rate and drive power as follows: Δp

1. dthe ebit transported by the rotating work machine increases linearly with the speed of the machine;
2. puterea drive increases linearly with the speed of the rotating machine and with the increase of total pressure achieved by the rotating work machine.

The increase of the speed of the machine is limited by the fact that the economic speed of the fluid in the suction connection of the rotating work machine should not exceed approx. 1 [m/s].

In conclusion, the flow rate transported by the rotating working machine is determined by the shape of the rotor, more precisely by the shape and height of the rotating piston.

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Chapter 7. Sizing of some elements of the hydraulic circuit of the rotating work machine

This chapter includes calculations on the sizing of the suction chamber and the discharge chamber of the rotating volume pump with profiled rotors.

For the correct dimensioning of the elements of the hydraulic circuit, account must be taken primarily of the load and pressure losses on the pipe route, so as to ensure the required pressure and water flow rate. In irrigation systems, another important element to be taken into account is the area on which it is necessary to apply watering.

The attempt to reduce the load losses is made by increasing the diameters of the pipes, within the permissible limit of the economic speeds. Thus, depending on the type of network, ranges of fluids are provided in the standards. With their help and the flow rates that are transported, the diameters of the pipes can be determined [22].

Taking into account all these aspects, the main elements of the hydraulic circuit of the rotating work machine have been dimensioned.

Chapter 8. Design, design and construction of the experimental installation

This chapter presents the diagram of the experimental installation, the principle of operation, the method of measurements, and the measuring devices used to transport out the experimental measurements.

The experimental installation was built in the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment of the University Politehnica of Bucharest, room CG131. It consists of:

1. two cylindrical tanks, one suction tank and one discharge of the transported fluid; rthe water ezervor (at the pump suction) at the top has two holes, one for water supply and one for ventilation. The level of the liquid inthe suction tank is kept at $h \geq 0.5$ [m];
2. m rotating working aeces with the following constructive parameters, z = 30 [mm], R_r = 50 [mm], R_c = 80 [mm];
3. melectric otor with anti-explosive protection;
4. cfrequency onverter;
5. debitmetru electromagnetic;
6. you get to adjust the flow rate and empty the circuit;
7. ametering and control parastats: thermometer, gauges, multimeter, ammeter.

The route of the hydraulic circuit of the experimental installation is made of transparent plexiglass pipes Ø 50 x 2 [mm], which allows a good visualization of the flow rate. Manometers and an electromagnetic flow rate meter were mounted on the route of the fluid circulation pipe. In order to modify the speed of the rotating working machine, an electric current frequency converter was provided [80]; the height of the water pumping is H_g = 4 [m].

Figure 8.2 shows a photograph of the experimental installation built in the laboratory in order to validate theoretical research.

Fig. 8. 1. General view of the experimental installation
1 – water suction tank; 2 – tap Dn 60 Pn 2 [bar]; 3 – pressure gauge at pump suction; 4 – electric motor of the pump; 5 – rotating working machine; 6 – pressure gauge at the pump discharge; 7 – flow rate meter; 8 – fluid flow rate control valve; 9 – supply panel; 10 – frequency converter; 11 – digital multimeter; 12 – ampermetric pliers; 13 – the discharge tank.

Working mode: Rotating work machine (5) toturn water from the tank (1); at the outlet of the rotating work machine measure the pressure of the water with the pressure gauge (6). The water flow rate transported by the rotating work machine is recorded on the screen of the electromagnetic flow rate meter (7) the water reaching the discharge tank (13) through the plexiglass pipe with nominal diameter Ø 50 x 2.

The valve (8) was provided for the adjustment of the water flow rate transported through the circuit in order to achieve the load characteristic.

Measurements are made at various speeds of the electric motor; the frequency converter allows the measurement and adjustment of the speed of the electric motor. Measurements of the electrical supply voltage of the electric motor are made with a digital multimeter connected to the terminals of the frequency converter. On the power cord between the switchboard and the converter, place an ampermetric pliers (clampmeter) with which the intensity of the electric current is measured.

Chapter 9. Experimental research and processing of the obtained results

Following the findings made during the period of operation of the pumping stations within the land improvement developments, the energy balances, the measurements carried out andthe low yields currently between 50 % and 70 %, it is justified the need to continue research in order to improve their parametersand replace the existing pumping aggregates, with equipment efficient in terms of electricity consumption and transported water volumes.

Experimentalresearch is to validate or not the theoretical aspects in order to improve their theoretically designed parameters of a rotating volume machine with profiled rotors.

Thus, the graphs of the functions are determined experimentally, and compared with those determined by theoretical means $\dot{V} = f(n_r)$ $P = f(n_r)$ $\eta = f(n_r)$, in Chapter 3.

The actual efficiency of the rotating work machine has been determined theoretically and the values are also determined experimentally, thus demonstrating that the constructive solution is functional and reliable.

The results of research on raising the characteristics of the rotating work machine that circulate fluids to different working parameters shall be presented .

1. *Experimental results for* $\dot{V} = f(n_r)$

By changing the speed, the flow rate transported by the car was also changed; by means of the electromagnetic flow rate meter, the flow rate transported through the experimental installation was measured.

The results from the theoretical calculations and the experimental results obtained are presented $\dot{V}_t$ $\dot{V}_r$ in Table 9.3. Based on this, the comparative graph of the variation of the theoretical flow rate/real flow rate was represented in Figure 9.1.

Table No. 9. 1. Theoretical and experimental flow rate values depending on the speed of the rotating work machine

n_r [rpm]	100	200	300	400	500
$\dot{V}_t\left[m^3/s\right]$	0,001966	0,003932	0,005898	0,007864	0,009830
$\dot{V}_r\left[m^3/s\right]$	0,00180	0,00363	0,00553	0,00747	0,00923

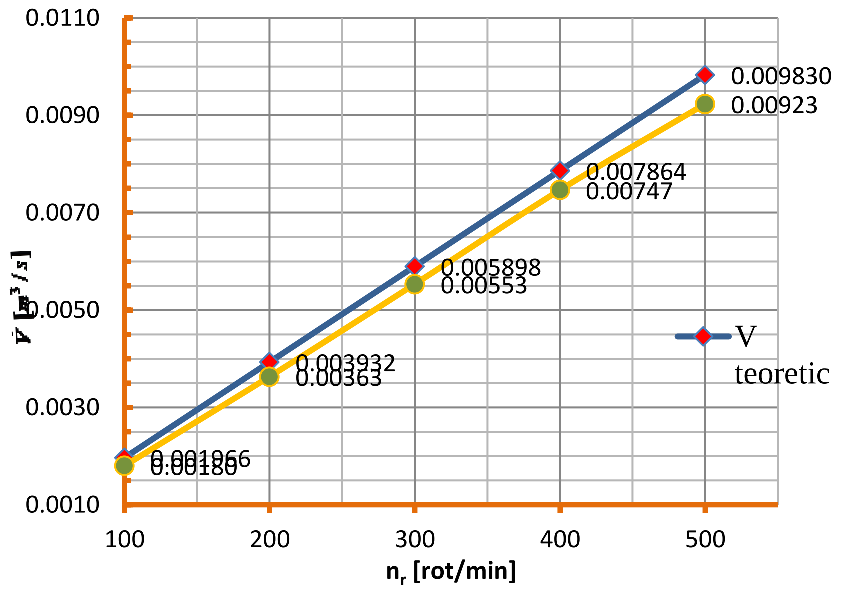

Fig. 9. 1. Graphs of the function $\dot{V} = f(n_r)$

$\dot{V}_t$ – the theoretical flow rate transported by the rotating machine; – the actual flow rate transported.$\dot{V}_r$

Figure 9.1 shows that the two graphs are very close; thus, the yield by volume is

$$\eta_v = \frac{\dot{V}_t}{\dot{V}_r}[\%] \tag{9.1}$$

Performing the calculations resulted in Table 9. 2 values of the volume efficiency at different speeds of the rotating working machine.

Tabelul nr. 9. 2. Values of volume efficiency depending on the speed of the car

n_r [rpm]	100	200	300	400	500
η_v	0,916	0,924	0,938	0,949	0,939

Based on the data in Table 9. Figure 2 was shown in Figure 9.2 the graph of the variation of the volume efficiency at different speeds of the rotating working machine.

Figure 9.2 shows that when the speed increases above a certain value $n_r \geq 400$ [rpm], the value of the volume yield decreases because the volume losses increase.

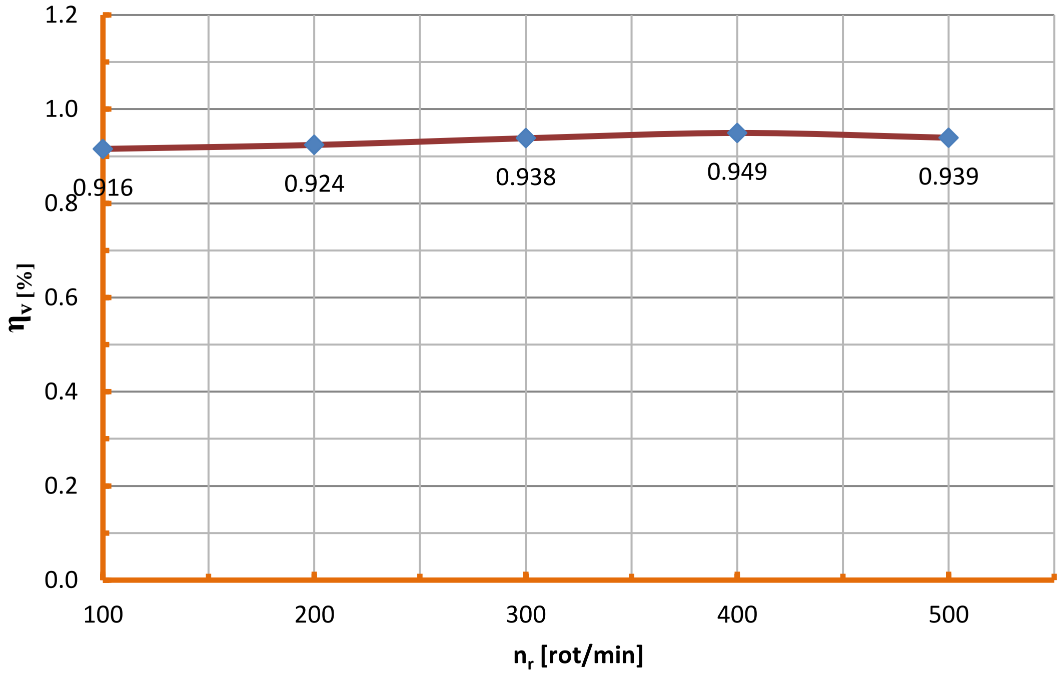

Fig. 9. 2. Graphical representation of the volume yield at different speeds of the rotating work machine.

B) Experimental results for P = f (n_r)

Voltage *U* and the intensity of electric current *I* for different speeds were measured.

Puterea at the motor coupling chosenric was calculated with the relation

$$P_{c,me} = P_{me} \cdot \eta_{me} \ [\text{W}], \tag{9.1}$$

in which ηme represents the actual efficiency of the electric motor, ηme = 0,747 [24].

1. **Values of measured quantities and calculation results obtained when the fluid being transported is water**

The results are presented in Table 9.3.

Table No. 9. 3. Values of electric motor power and electric motor coupling power experimentally established when the transported fluid is water

n_r [rpm]	**200**	**300**	**400**	**500**
H [m H_2O]	4	4	4	4
I [A]	0,63	0,95	1,28	1,6
U [V]	380	380	381	381
cosφ	0,71	0,71	0,71	0,71
$P_{me} = \sqrt{3}\, U \cdot I \cdot \cos\varphi$ [W]	294,39	443,93	599,71	749,64
$P_{c,me} = P_{me} \cdot \eta_{me}$ [W]	219,91	331,61	447,98	559,98

1. **Values of measured quantities and calculation results obtained when the fluid being transported is engine oil**

Table No. 9. 4. Values of electric motor power and electric motor coupling power experimentally established when the transported fluid is engine oil

n_r [rpm]	**200**	**300**	**400**	**500**
H [m H_2O]	4	4	4	4
I [A]	0,6	0,9	1,18	1,45
U [V]	380	380	381	381
cosφ	0,71	0,71	0,71	0,71
$P_{me} = \sqrt{3}\, U \cdot I \cdot \cos\varphi$ [W]	280,38	420,56	552,86	679,36
$P_{c,me} = P_{me} \cdot \eta_{me}$ [W]	209,44	314,16	412,98	507,48

Based on the data from 9.3 and 9.4, figures 9 were plotted in Figure 9. 3, functions and . $P_{me} = f(n_r)$ $P_{c,me} = f(n_r)$

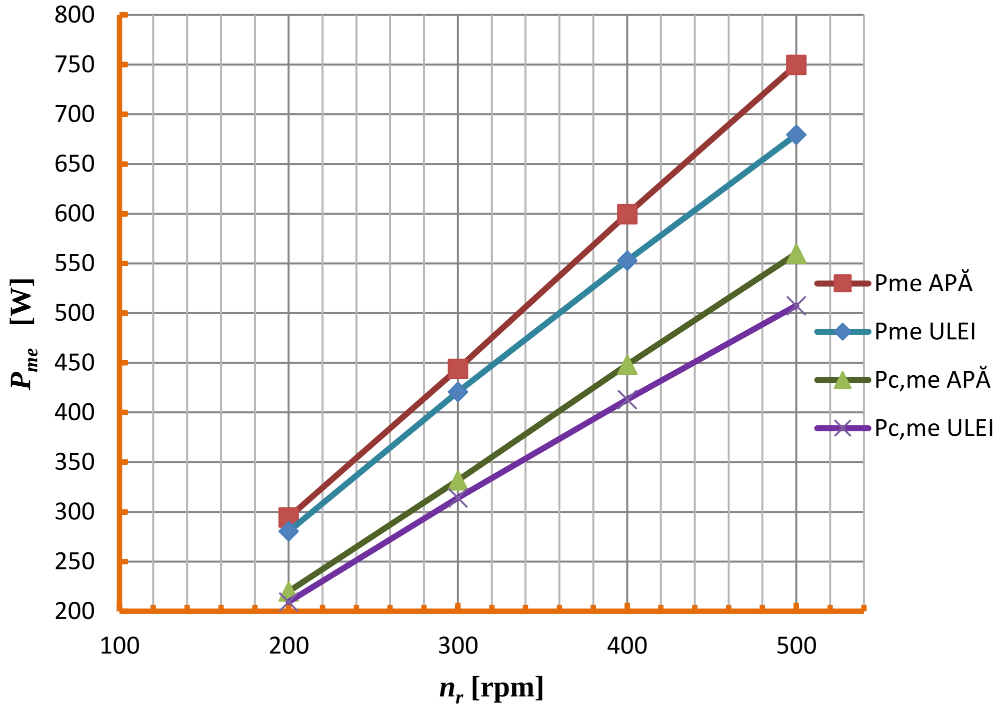

Fig. 9. 3. Graphical representation of the puterii of the electric motor and of the power at the coupling of the electric motor
experimentally established when the transported fluid is water and engine oil 23]

Taking into account the actual efficiency of the pump η_p, the result is the actual power that serves to circulate the fluid $P_{c,p}$.

From the paper [24] is adopted $\eta_p = 77\%$

The power at the electric motor coupling $P_{c,me}$ [W] determinated experimentally must have values close to the puterea at the pump coupling $P_{c,p}$ [W]. By doingthe calculations, thedata in Table 9.5 are obtained.

Table No. 9. 5. Values of the drive power required to circulatethe fluid

n_r [rpm]	200	300	400	500
$P_{c,p,apă}$ [W]	285,60	430,67	581,80	727,25
$P_{c,p,ulei}$ [W]	272,00	408,00	536,34	659,07

Based on the data in Table 9.3, 9.4 and 9.5,the graphs $P_{c,p} = f(n_r)$ and $P_{c,me} = f(n_r)$ in Figure 9 were drawn. 4.

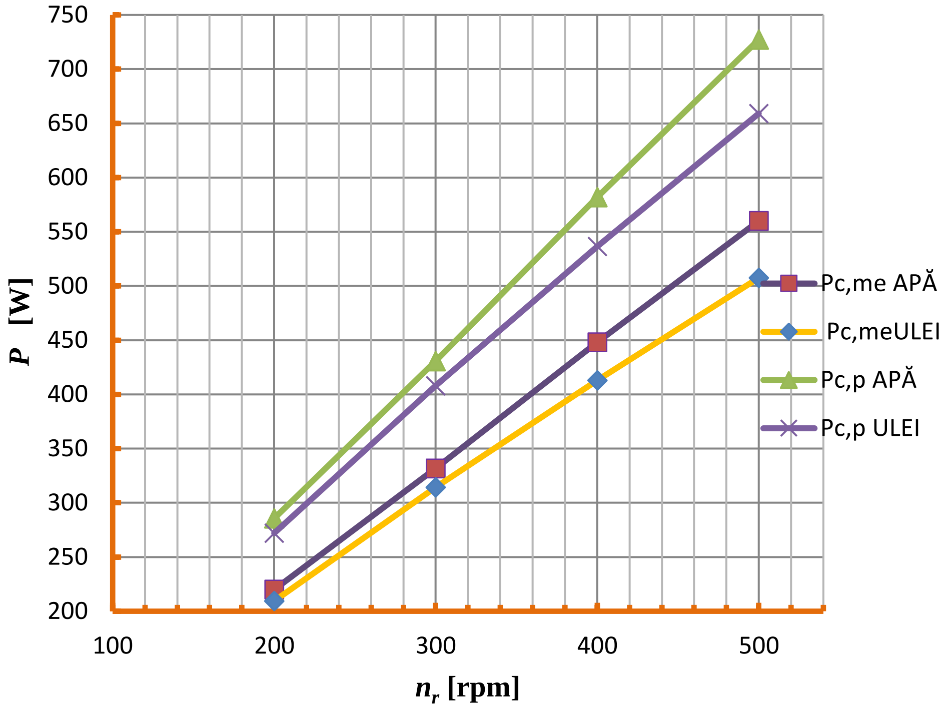

Fig. 9. 4. Graphical representation of the power change at the electric motor coupling ($P_{c,me}$) and the power at the pump coupling ($P_{c,p}$)

A good coincidence is observed between the values calculated theoretically and those determined experimentally.

The actual power consumed by the pump when transport engine oil is lower than when circulating water, since the losses by mechanical friction between the rotors and the housing are lower when transport the oil.

C) Experimental results for the characteristic curves of the rotating work machine

The theoretical results obtained for the characteristic curves have been compared with the results obtained from experimental research.

In order to draw the characteristic of power were measured U, I, n_r, $\dot{V}$. Dsplints obtained are shown in Table 9.6.

Table No. 9. 6. Values of the drive power according to the pressure increase

H_p [mH_2O]	2	4	6	8	10
Δp [N/m^2]	$0,2 \cdot 10^5$	$0,4 \cdot 10^5$	$0,6 \cdot 10^5$	$0,8 \cdot 10^5$	$1 \cdot 10^5$
n_r [rpm]	300	300	300	300	300
$\dot{V}_r \left[m^3/s\right]$	0,00553	0,00553	0,00553	0,00553	0,00553

P [W]	110,67	221,33	332,00	442,67	553,33

Based on the data obtained, the function $P = f(\Delta p)$ in Figure 9.5 was graphically represented.

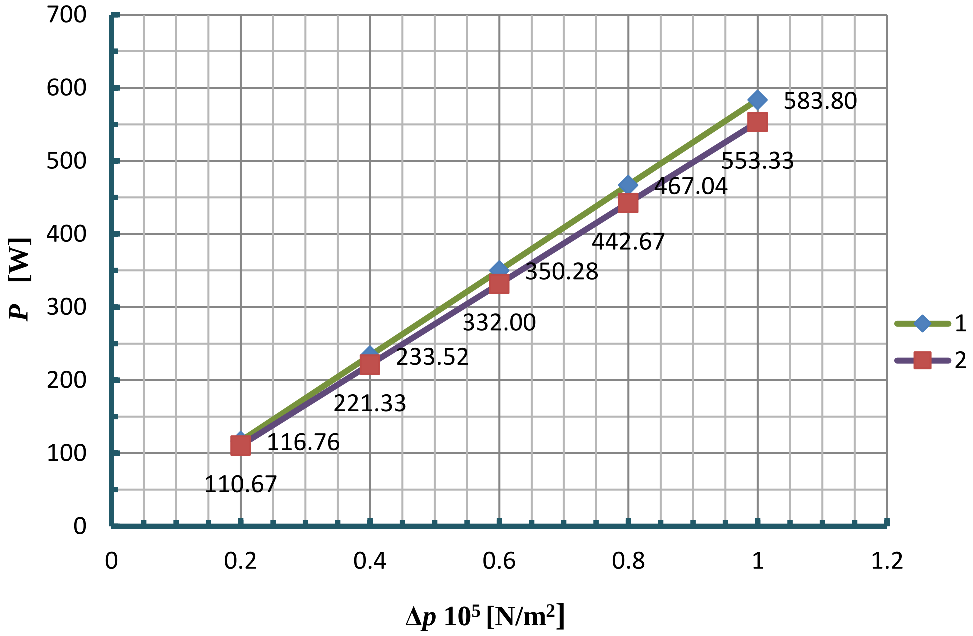

Fig. 9. 5. Graph of drive power according to the pressure increase
1- theoretical results; 2 - experimental results

A good coincidence between the results obtained theoretically and experimentally obtained is observed (fig. 9.5). At the same time, it can be noted that, depending on the increase in pressure achieved by the machine, the drive power of the machine also varies .

Multiplying the power of the electric drive motor of the car by the electric power absorbed indicated as a percentage on the dial of the speed regulator, the result is the power absorbed by the machine.

By performing the calculations haveresulted at the data in Table 9.9; $\dot{V}_t$ represents the theoretical volume flow rate, and $\dot{V}_r$ represents the real volumetric flow rate.

Table No. 9. 7. Effective efficiency values depending on the speed of the car

n_r [rpm]	100	200	300	400	500
α	90	70	50	30	10
$\dot{V}_t$ [m^3/s]	0,001966	0,003932	0,005898	0,007864	0,009830
$\dot{V}_r$ [m^3/s]	0,001800	0,003633	0,005533	0,007467	0,009233
Δp [N/m^2]	0,2	0,21	0,22	0,23	0,24
η_v	0,916	0,924	0,938	0,949	0,939

η_m	0,9	0,9	0,9	0,9	0,9
η_{ef}	0,824	0,832	0,844	0,855	0,845

Based on the data from Table 9.9, the efficiency characteristic of the rotating work machine was graphically represented in Figure 9.6 $\eta_{ef} = f(\Delta p)$; at the increase of the speed n_r the value of the yield η_v decreases.

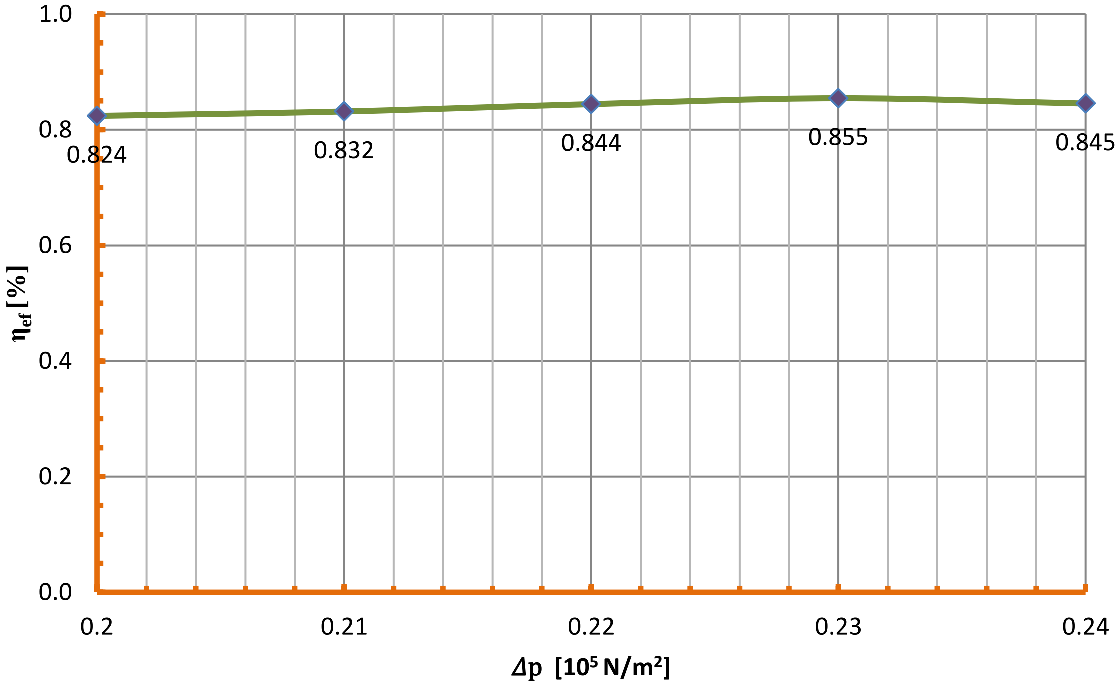

Fig. 9. 6. Reprezentarea grafică a funcției $\eta_{ef} = f(\Delta p)$

The values obtained in paragraph (9.3) are similar to the data in the literature [13], [25], [26], [227].

CONCLUSIONS

C.1. General conclusions

It reveals the advantages of rotating work machine, some constructive solutions being "*reversible*", i.e. the same constructive solution (rotating work machine with two profiled rotors and with pistons in the shape of a triangular prism or with curvilinear side faces) can be used as a work machine (pump, compressor) or motors. The analyzed constructive solution is based on a patent [28] and was conceived, designed and realized in the laboratories of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment of the Polytechnic University of Bucharest.

From the class of rotating work machine, a rotating work machine with prismatic pistons of triangular section was presented in the work, which can circulate any fluid substance

1. pure liquids (clean);

2. liquids with suspensions;
3. polyphase fluids (water + sand, water + ash);
4. fluid reologice;
5. fluid from the food industry: water, wine, oil.

The aspirated fluid is transported to discharge with minimal energy loss; thus the engine moment M is $\overrightarrow{M} = \vec{F} \cdot \vec{b}$; $M = F \cdot b \cdot \sin\alpha$, in which the b arm of force F is perpendicular to the force, i.e. . This leads to an advantage over piston machine and crank rod system $\sin\alpha = \sin 90^{\circ} = 1$.

In addition, the constructive solution does not contain elements that perform alternative rectilinear movements; it shows safe operation and easy maintenance.

When building it, increased accuracy is required due to the fact that if there are large games between the rotor and the case, the volume r andament of the pump decreases.

The constructive solution proposed in this work was designed and built in the laboratory, where a stand was also made for its testing.

The designed and built stand is in open circuit.

Making this machine does not require special technologies or more special materials.

The work offers a large volume of specialized knowledge in the field of rotating volume machine with profiled rotors, machine designed for the circulation of polyphase fluids.

C.2. Original contributions

Taking into account the proposed objectives, and analyzing the theoretical and experimental results obtained during the elaboration of this doctoral thesis, a series of original contributions can be highlighted, the most representative of which are:

● **Theoretical contributions:**

1. Conducting a study of the current state of research on rotating work machines with profiled rotors, based on the consultation of a representative bibliography and the discerning selection of valuable works.
2. Identification and presentation in a coherent scientific manner of the problems related to the influence of geometric and functional parameters on the flow rate and drive power of the rotating work machine.
3. The design and realization of a constructive solution of the rotating work machine with two profiled rotors, for which the radius of the rotor R_r remained equal to 50 [mm], and the height of the rotating piston z has been increased to 48 [mm], showing elements of originality in the field of rotating work machines with profiled rotors that serve to circulate fluids; by increasing the height of the piston, the usable volume is increased, as a result the flow of fluid circulated by the rotating working machine is increased.
4. Establishing mathematical relationships between the constructive elements of the machine such as:
   - itis between the radius of the rotor and the height of the rotating piston;
   - cthe oration between the radius of the housing and the height of the rotating piston.
5. Detailed exposure of the method of calculating the coordinates x_i and y_i that define the contour of a quarter rotor, with the consideration of the parametric equations of the movement of the top of the piston of the lower rotor inside the upper rotor cavity, on the circle of the rotor radius and on one side of the rotating piston, and the use of a corresponding Excel program.

6. Establishing mathematical, original relationships that define the profile of a special architecture rotor and other links between:

- the speed of the rotating work machine and the flow circulated by it.
- the height of the piston and the drive power of the rotating work machine.

7. The theoretical construction of the characteristic curves of the original rotating work machine proposed, being given the geometrical elements l, R_r, z and functional elements n_r, Δp.

● **Numerical contributions:**

1. The general character of the mathematical model for calculating the coordinates of the rotor profile contour of the original proposed work machine by using an Excel program, which can be modified for other dimensions of the work machine, being necessary to specify only the values of the rotor radius and the height of the piston.
2. Graphical construction, in Excel, based on the coordinates obtained by the mathematical model, the profile of the rotating piston and the introduction of data into the Catia Dassault System program, for modeling the rotor part.
3. Establishing, starting from the complex geometric shape of the rotor, difficult to obtain by classical procedures, of the execution by chipping, using profiled tools - monoblock cutters made of metal carbides or profiled mills reinforced with hard plates, on numerically controlled milling machines.
4. The proposal to elaborate a program for the construction of the rotor on a cnc machining center, the execution programs on milling machines being obtained using the CATIA V5 program.
5. Numerical determination and graphical display of results.

● **Experimental contributions:**

1. Design and development of the laboratory installation for the experimental study of the rotating work machine with profiled rotors, equipped with equipment suitable for research (electric motor with anti-explosive protection; frequency converter), with high-performance measuring and control equipment (digital thermometer, digital differential gauges, digital multimeter for measuring the voltage, intensity and frequency of current, electromagnetic flow meter, electronic data recording and processing system).
2. Specification and detailing of the purpose of experimental research, indicating the sequence of the measurement stages.
3. Exposing the methodology of experimental research and enumerating operations to validate the flow curve according to speed and power according to speed, for H = 4 [m] = const.
4. Determination of the volume efficiency of the machine studied for different speed values.
5. Determination of the values of electric motor power and electric motor coupling power, when the fluid being conveyed is water and when the fluid being conveyed is engine oil.
6. Experimental construction of the caractrerist curves of the rotating work machine with profiled rotors, the load characteristic, the power characteristic and the efficiency characteristic, and the comparison with the characteristic curves obtained theoretically.
7. Suggestive presentation of the obtained experimental results, tabular and graphical, for all the investigated cases and the comparison of the experimentally determined results with the results obtained theoretically (finding a good concordance).

C.3. Perspectives for further development of research

Taking into account the theoretical and experimental research carried out in this doctoral thesis,this rotating work machine can be used in agriculture to compensate for the soil water deficit for precision irrigation, ensuringthe controlled supply of soil and plants with the quantities of water according to the regime of maintaining the humidity in the calculated soil , but also in pumping stations in order to eliminate excess water from the ground and drainage, as this rotating work machine can also handle dirty water with suspended solid particles.

The positive effect forecasted by the modernization of the land improvement facilities is the improvement of the operating efficiency of the pumping aggregates, the reduction of the electricity consumptions and implicitly the reduction of the expenses for pumping the water.

Also, this rotating machine, depending on the materials used in its construction, can circulate food fluids such as oil, wine, alcohol, spirits, etc.

The construction of the rotating working machine with prismatic rotating pistons of triangular section presented in Chapter 4 and 5 was not made of metal because the costs related to its realization could not be borne by the PhD student. This could be done on a larger scale, depending on the water needs requested by the beneficiary.

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