

Energy-efficient Rotary Working Machine with Profiled Rotors for Fluid Handling and Low-power Transport Applications

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Abstract

The paper presents a rotary working machine of the volumetric type with profiled rotors, designed and built within the Department of Thermotechnics of the National University of Science and Technology "POLITEHNICA" of Bucharest. Beyond its mechanical novelty, the machine addresses a key energy-engineering challenge: reducing the specific energy consumption of pumps and ventilation systems used in industrial processes. Rotary positive displacement machines typically operate with high mechanical losses, but the profiled-rotor architecture used here significantly reduces dissipative effects associated with leakage, mechanical friction, and hydrodynamic inefficiencies. Theoretical evaluations and experimental tests demonstrate that the architecture can operate at lower driving power for a given volumetric flow rate, thus increasing energy efficiency compared with conventional lobe, vane, or screw pumps. These characteristics make the machine suitable for applications in sustainable fluid transport, energy-efficient HVAC systems, low-pressure gas handling, and renewable-energy-related processes where reduced power consumption is essential.

Keywords: Rotary Pump, Profiled Rotors, Volumetric Machine, Fluid Transport, Mechanical Engineering.

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Constructive Principle

In this type of machine, we do not have components with translational motion, nor do we have valves, etc.

The machine has increased reliability, and for its construction no special materials or technologies are required. The essential element is the construction of the rotors, for which a calculation program is available that can be adapted to a numerical control (C.N.C.) machining center.

Constructive and Functional Considerations

The constructive solution of the rotary volumetric machine with two specially machined rotors provides a basis for extending scientific research concerning the problems that arise in the transport of clean fluids or fluids containing suspensions.

For this working machine, the advantage lies in the fact that the drive torque received by the machine's shaft is used almost entirely for the transport of the fluid; furthermore, there are no translational motions of the machine's components, which leads to achieving an efficiency significantly superior to that of piston pumps.

In rotary working machines with profiled rotors, efforts focus on optimizing the rotor architecture and selecting working parameters so that an efficient transport of the conveyed fluids is obtained [1,2].

The rotary machine presented in the paper can operate as a rotary volumetric pump for transporting liquids.

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Cap 1: Rotary Machines in the Field of Fluids

Classification of Rotary Machines

Machines are assemblies used for transforming energy from one form into another with the help of a moving element (piston, profiled rotor, blade).

Machines, according to their intended purpose, are divided into two major categories [1-3]:

1. Prime movers (force machines), which transform a certain form of energy into mechanical energy (internal combustion engines, steam or gas turbines, etc.).
2. Working machines, which transform mechanical energy into potential pressure energy (fans, pumps, compressors).

Force machines and working machines that are traversed by fluids, depending on the variation of flow parameters, are classified as follows:

- a. Hydraulic machines, which convey or are driven by liquids, where thermal phenomena can be neglected.
- b. Thermal machines, which convey gases or vapors (or are driven by them), where the thermal phenomena that occur cannot be neglected.

The development of rotary working machines (pumps, fans, blowers) with high performance is of current interest.

Table 1: General Classification Table of Rotary Machines

| According to the intended purpose | Depending on the constructive solution | According to operating parameters |
|-----------------------------------|--|---|
| Working machines | Machines with profiled rotors | a) Fans, blowers, pumps |
| | Machines with blades | b) Fans, blowers |
| Prime movers (force machines) | Machines with profiled rotors | c) Internal combustion engines, steam or gas engines, pneumatic engines |
| | Machines with blades | d) Steam turbines, gas turbines |

Research aims at designing and building machines that ensure the transformation of the driving torque received by the shaft into useful effects, but with energy losses kept as low as possible.

Rotary Working Machines for Fluid Transport

A more difficult problem consists in developing a rotary machine that can be used either as a working machine or as a prime mover, meaning that theoretically it should be a “reversible” machine [4,5].

Such a type of machine must ensure:

- The transformation of useful torque with minimal losses when it operates as a working machine;
- The full utilization of the energy of the working fluid for driving the shaft when it operates as a prime mover.

| | | |
|------------------------------------|-------------------|--------------------------|
| A) Positive Displacement Pumps | Piston pumps | a) Single-cylinder pumps |
| | | b) Multi-cylinder pumps |
| | | c) Axial-piston pumps |
| | Rotary pumps | d) Vane pumps |
| | | e) Gear pumps |
| | | f) Screw pumps |
| | | g) Lobe pumps |
| B) Non-Positive Displacement Pumps | Centrifugal pumps | |
| | Axial pumps | |

Among the working machines presented earlier, this paper analyzes a rotary volumetric pump with profiled rotors, which has the same operating principle as a lobe pump [6,7].

The advantages of rotary working machines are highlighted, some constructive solutions being “reversible,” meaning that the same constructive solution can be used either as a working machine (pump, compressor) or as a prime mover (engine). The constructive solution analyzed is based on a patent and was conceived, designed, and built in the laboratories of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment of the POLITEHNICA University of Bucharest [6,7].

From the class of rotary working machines, the paper presents a new type of rotary volumetric machine that can convey any fluid substance, including [8]:

- Pure liquids (clean);
- Liquids with suspensions;
- Two-phase fluids (water + sand, water + ash);
- Rheological fluids;
- Fluids from the food industry: water, wine, oil.

Operation of the Rotary Machine with Profiled Rotors

The rotary machine will be analyzed as being composed of two profiled rotors, each rotor being equipped with two rotary pistons of triangular shape.

The machine consists of two rotors (3, 4) with the same rotational speed, which rotate inside housings (2, 5). The synchronous rotation of the two rotors is ensured by a cylindrical gear system consisting of two helical gears, mounted either inside or outside the machine.

The gears have the same pitch diameter and are mounted on shafts (7) and (8); they ensure a rotational motion such that the rotary pistons (6) of the upper rotor enter the cavities (10) of the lower rotor.

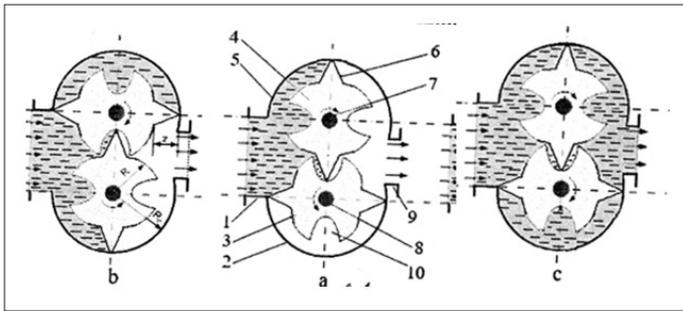


Figure 1: Principle of Operation of the Rotary Volumetric Machine

1 – suction chamber; 2 – lower housing; 3 – lower rotor; 4 – upper rotor; 5 – upper housing; 6 – rotary piston; 7 – driven shaft; 8 – driving shaft; 9 – discharge chamber; 10 – cavity into which the piston of the upper rotor enters.

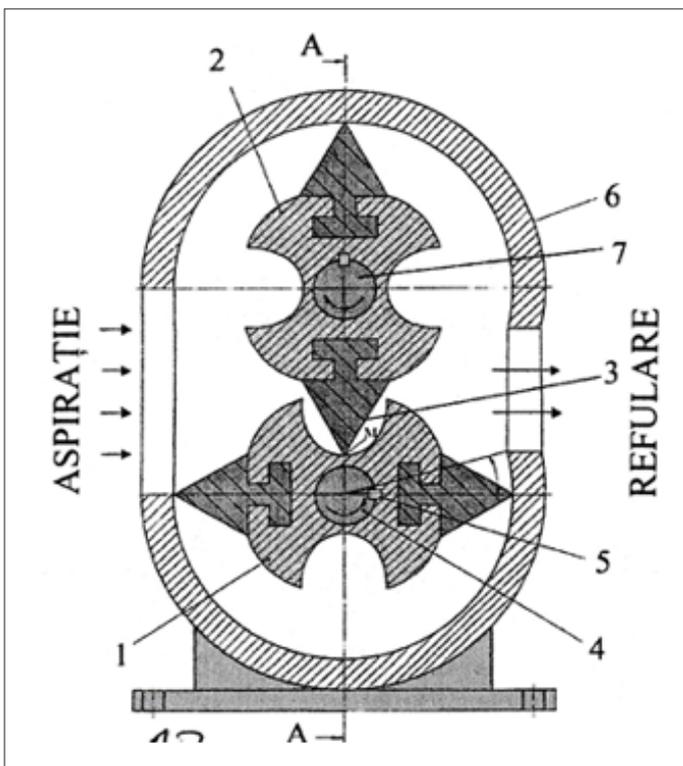


Figure 2: Section Through the Rotary Working Machine

1 – lower rotor; 2 – upper rotor; 3 – triangular piston; 4, 7 – shafts; 5 – key; 6 – upper housing

Along the rotor with length (l), the contact point (M) will describe a line of contact between the rotary piston (3) and the lower rotor (1) (Figure 2).

The profile of the profiled rotor was established mathematically, meaning that the coordinates (x_i, y_i) and the manufacturing technology were specified [6,7].

The constructive solution for the rotary machine was designed and built in the laboratory of the Faculty of Mechanical Engineering and Mechatronics, Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment of the Politehnica University of Bucharest.

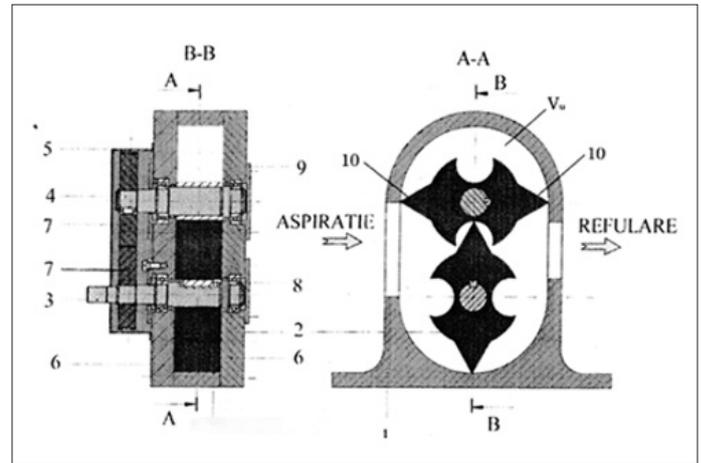


Figure 3: Longitudinal Section Through the Profiled Rotary Working Machine

1 – oval housing; 2 – profiled rotor; 3 – driving shaft; 4 – driven shaft; 5 – oil chamber; 6 – lateral wall; 7 – gears; 8 – bearing; 9 – bearing cover; 10 – rotary piston.

In Figure 3 the gears (7) mounted outside the machine can be observed, which ensure the synchronous rotation of the two rotors.

Energy Considerations in Rotary Working Machines

In modern energy systems, pumps and ventilators account for more than 20–30% of industrial electricity consumption. Improvements in rotary positive-displacement machines therefore contribute directly to reducing operating costs and environmental impact. Energy losses in such machines arise primarily from mechanical friction, volumetric leakage, viscous dissipation, and non-optimal flow channel geometry. The profiled-rotor machine presented in this paper was conceived to minimize these losses through synchronous rotor motion, absence of valves, and nearly constant angular velocity, leading to a smoother torque profile and reduced power spikes. As a result, the machine achieves a favorable ratio between useful hydraulic power and driving mechanical power, improving its energy efficiency when compared with conventional technologies such as lobe pumps, vane pumps, or gear pumps. Such characteristics integrate well into energy-intensive installations such as district heating networks, process cooling loops, geothermal circuits, and renewable-energy-driven pumping systems.

Calculation of the Flow Rate Conveyed by the Rotary Machine

The machine consists (Figure 4) of two rotors (2, 5) identical in special shape, which rotate with the same speed inside housings (1).

1 – lower housing; 2 – lower rotor; 3 – suction chamber; 4 – upper housing; 5 – upper rotor; 6 – rotary piston; 7 – driven shaft; 8 – discharge chamber; 9 – driving shaft; 10 – cavity into which the piston of the upper rotor enters.

After a rotation of 180° , the fluid contained in the useful volume V_a (Figure 1.c), meaning the space between the pistons, the lower housing (1), and the lower rotor (2), will be sent into the discharge chamber.

With one complete rotation of the shaft (9), two such volumes will be transported from suction to discharge.

Volumetric flow rate formula:

$$V_a = 2(z + R_r) \cdot l \text{ [m}^3/\text{rot]}$$

where:

- R_c – casing radius
- R_r – rotor radius
- z – piston height
- l – rotor length

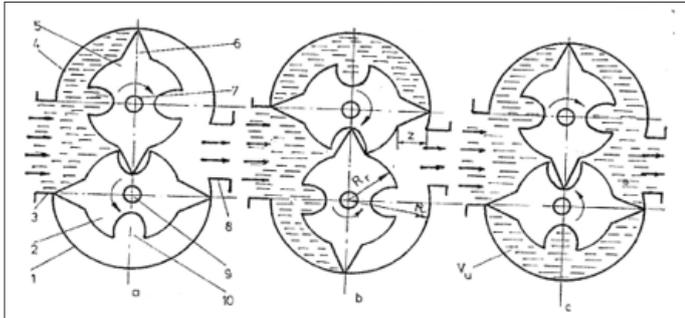


Figure 4: Position of the Rotors after a 90° Rotation

1 – lower housing; 2 – lower rotor; 3 – suction chamber; 4 – upper housing; 5 – upper rotor; 6 – rotary piston; 7 – driven shaft; 8 – discharge chamber; 9 – driving shaft; 10 – cavity into which the piston of the upper rotor enters.

The aspirated fluid (figure 4.a) is transported toward the discharge chamber, and after a 90° rotation of both rotors the situation shown in figure. 4.b is reached, and subsequently in figure 4.c.

After a 180° rotation, the fluid contained in the useful volume V_u (figure 4.c), i.e., in the space between the pistons, the lower housing (1) and the lower rotor (2), will be sent into the discharge chamber.

With one complete rotation of the shaft (9), two such volumes will be transported from suction to discharge [9].

$$\dot{V}_u = 2 \cdot ((\pi R_c^2 / 2) - (\pi R_r^2 / 2)) \cdot l \text{ [m}^3/\text{rot}] \tag{2.1}$$

$$R_c = R_r + z \text{ [m]} \tag{2.2}$$

$$\dot{V}_u = \pi l z (z + 2R_r) \text{ [m}^3/\text{rot}] \tag{2.3}$$

The volumetric flow rate of fluid discharged by a single rotor with length l [m] and rotational speed n_a [rot/min] will be:

$$\dot{V}_u = \pi l z (z + 2R_r) \cdot n / 60 \text{ [m}^3/\text{s}] \tag{2.4}$$

Since the machine has two identical rotors, the total flow rate conveyed by the machine will be:

$$\dot{V}_m = 2\dot{V}_u = \pi l z (z + 2R_r) \cdot n / 30 \text{ [m}^3/\text{s}] \tag{2.5}$$

From relation (2.5) it can be observed that the flow rate of the machine varies according to the following parameters:

Calculation of the Theoretical Driving Power of the Rotary Machine

The theoretical driving power of the working machine will be calculated based on the volumetric flow rate – pressure variation relation:

$$P = \dot{V} \cdot \Delta p \tag{2.6}$$

where Δp is the pressure increase between suction and discharge.
 $\Delta p = p_r - p_e \text{ [N/m}^2\text{]} \tag{2.7}$

p_r – pressure of the fluid at discharge

p_e – pressure of the fluid at suction

Beyond the theoretical definition of power, the efficiency of a rotary machine is evaluated by comparing the useful hydraulic power ($\dot{V} \cdot \Delta p$) with the mechanical power supplied to the shaft. The rotary machine with profiled rotors benefits from minimal oscillatory torque and the absence of reciprocating masses, which reduces energy losses typically encountered in piston pumps and even some lobe-type volumetric pumps. This structural characteristic provides an opportunity to operate the machine at lower input power for the same fluid flow rate, contributing to improved global energy efficiency. Experimental evaluation confirms that the power demand is stable across operational ranges, which is beneficial for frequency-controlled electric drives, commonly used in energy-optimized installations.

In Figure 5 an axonometric sketch of the model of the rotary machine built from transparent plexiglass can be seen; if the rotors rotate in the direction indicated by the arrows drawn on the rotors, then the fluid is conveyed from suction to discharge.

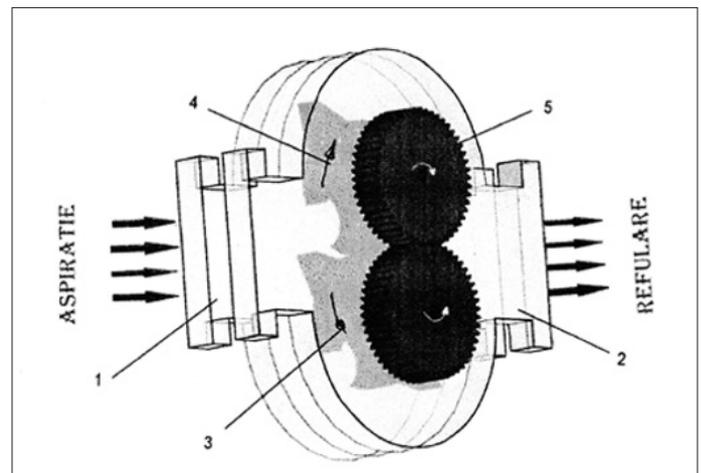


Figure 5: Axonometric view of a model of a volumetric pump with two profiled rotors

1 – suction chamber; 2 – discharge chamber; 3 – lower rotor; 4 – upper rotor; 5 – cylindrical gear.

This type of working machine has the advantage that it can convey to the discharge chamber (2) any viscous fluid or fluids with suspensions that enter the suction chamber (1), as well as other fluid substances that do not attack the material from which the rotors and housings are made.

The experimental tests were analyzed, and based on the results of the experimental measurements it was found that the constructive solution presented ensures good sealing between the high-pressure side (discharge) and the low-pressure side (suction) of the working machine.

Cap 2: Use of the Rotary Machine

Diagram of the Installation when the Rotary Machine is Used as a Volumetric Pump

In Figure 6 the schematic of the experimental installation is presented.

This installation was conceived, designed, and built for the purpose of validating the theoretical results obtained during the theoretical research.

The hydraulic circuit of the experimental installation is made of transparent plexiglass pipes $\varnothing 50 \times 2$ mm, which allows good visualization of the flow. Along the circulation line of the fluid, manometers, thermometers, an electromagnetic flowmeter, and the pump speed can be modified using a frequency converter for the electric current.

The installation operates in an open circuit and was built in the laboratory of the Department of Thermotechnics, Engines, Thermal and Refrigeration Equipment at the Politehnica University of Bucharest, room CG131.

The measuring devices are modern, with digital display and high precision [10,11].

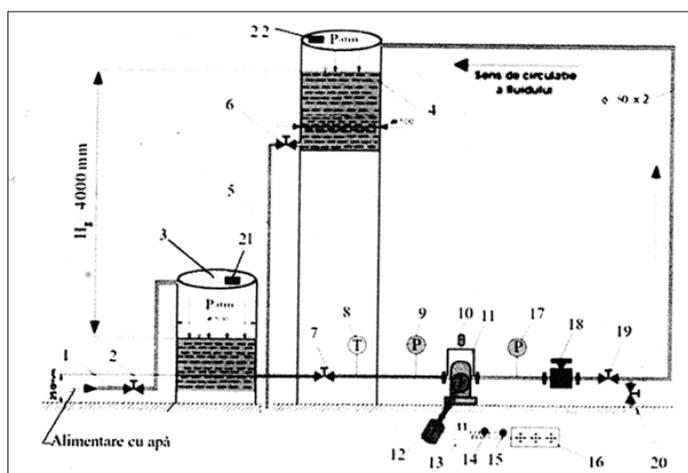


Figure 6: Sketch of the experimental installation equipped with a ventilator

1 – pipe; 2 – valve; 3 – water reservoir; 4 – discharge reservoir; 5 – discharge pipe of the water reservoir; 6 – drain valve of the water reservoir; 7 – valve Dn 60 Pn 2 bar; 8 – thermometer; 9 – manometer; 10 – differential manometer; 11 – rotary volumetric machine; 12 – electric motor; 13 – frequency converter; 14 – ammeter; 15 – multimeter; 16 – 380 V AC power source; 17 – manometer at pump discharge; 18 – electromagnetic flowmeter; 19 – flow-regulating valve; 20 – circuit drain valve; 21 – 22 – vent plugs.

The experimental installation shown in Figure 6 can also be used for testing other types of pumps.

The pressure, temperature, and fluid flow measuring devices are modern.

The installation operates in an open circuit; the conveyed fluid may be water from the supply network when the machine

operates as a rotary volumetric pump, or atmospheric air when it operates as a ventilator [12-14].

When the machine operates as a pump or ventilator, the energy demand becomes a critical parameter for system integration. Due to the geometry of the profiled rotors, the internal pressure rise occurs with reduced turbulence and minimal re-circulatory eddies, which typically contribute to energy losses. Consequently, the machine can operate efficiently at lower rotational speeds, directly impacting the electrical energy required to maintain a given flow rate. This advantage is particularly important for decentralized renewable-energy installations, wastewater treatment circuits, low-pressure gas conveyance, and HVAC energy-saving applications. Moreover, its compatibility with frequency-converter control supports advanced energy-optimization strategies, such as variable-flow pumping and intelligent load management [15,16].

Diagram of the Installation when the Rotary Machine is Used as a Ventilator

In Figure 7 the schematic of the experimental installation is presented for the case in which the rotary machine operates as a ventilator (or low-pressure compressor).

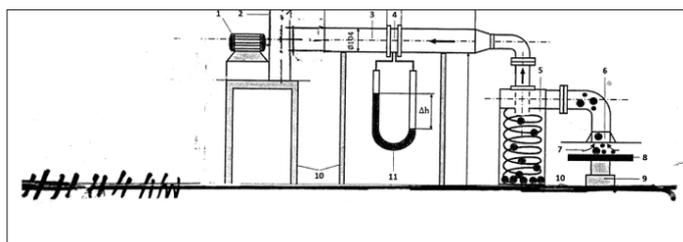


Figure 7: Sketch of the experimental installation

1 – electric motor; 2 – ventilator; 3 – suction duct; 4 – diaphragm; 5 – cyclone; 6 – suction hood; 7 – particles; 8 – observation plate; 9 – lifting device; 10 – support; 11 – differential manometer.

In rotary working machines with profiled rotors, the issue concerning the rotor architecture is the optimization of its geometry and the selection of parameters that lead to more efficient conveyance of fluids.

Minimizing the driving power of volumetric machines with profiled rotors and finding a new architecture for the profiled rotor are key elements in the conception and design of a new rotary machine.

In working machines (pumps, ventilators, compressors), we encounter a flow system with a certain configuration that is characterized by specific constructive dimensions and certain functional parameters [17-19].

References

1. Băran N (2001) Rotating Thermic Machines. Working Machines. Force Machines (in Romanian), MATRIXROM Publishing House, Bucharest.
2. Motorga A (2011) Influence of Constructive and Functional Parameters on the Performances of Rotating Machines with

- Profiled Rotors (in Romanian). PhD Thesis, Faculty of Mechanical Engineering and Mechatronics, POLITEHNICA University of Bucharest.
3. Băran N, Duminiță D, Besnea D, Detzortzis A (2012) Theoretical and Experimental Researches Regarding the Performances of a New Type of Rotating Machine with Profiled Rotors. *Advanced Materials Research* 489: 1757-1761.
 4. Băran N (2003) Working Rotating Thermic Machines. Machines with Profiled Rotors. *Blade Machines* (in Romanian). MATRIXROM Publishing House, Bucharest.
 5. Băran N, Răducanu P (2010) Bases of Technical Thermodynamics. *Technical Thermodynamics*, POLITEHNICA PRESS Publishing House, Bucharest.
 6. Gheorghe G, Besnea D, Băran N, Constantin M, Hawas MN (2015) Experimental Research Regarding the Determination of the Effective Efficiency of a New Type of Volumetric Pump with Profiled Rotors. 7th International Conference on Innovations, Recent Trends and Challenges in Mechatronics, Mechanical Engineering and New High-Tech Products Development, MECAHITECH 15 International Conference, Bucharest, Romania.
 7. Motorga A, Băran N (2012) Theoretic and Experimental Research on the Characteristic Diagrams of a New Type of Rotating Machine with Profiled Rotors. *Scientific Bulletin, Series D: Mechanical Engineering* 74: 3.
 8. Marinov A (1994) Fluid Mechanics and Hydro-Pneumatic Machines (Part II). Politehnica University of Bucharest.
 9. Băran N (2003) Working Rotating Thermic Machines. Machines with Profiled Rotors. *Blade Machines* (in Romanian), MATRIXROM Publishing House, Bucharest.
 10. Motorga A (2011) Influence of Constructive and Functional Parameters on the Performances of Rotating Machines with Profiled Rotors (in Romanian). PhD Thesis, Faculty of Mechanical Engineering and Mechatronics, POLITEHNICA University of Bucharest.
 11. Băran N, Duminiță D, Besnea D, Detzortzis A (2012) Theoretical and Experimental Research Regarding the Performances of a New Type of Rotating Machine with Profiled Rotors. *Advanced Materials Research* 489: 1757-1761.
 12. Băran N, Motorga AO, Duminiță D (2011) Research Regarding the Building of an Experimental Setup for Testing a New Type of Rotating Machine with Profiled Rotors. *Rev. Mecatronica* 27-30.
 13. Băran N (2008) Elements of Computing the Architecture and Manufacturing Technology for a New Type of Profiled Rotor. International Conference, 6th Workshop on European Scientific and Industrial Collaboration on Promoting WESIC'08, Bucharest.
 14. Costache A, Băran N (2008) Computation Method for Establishing the Contour of a New Type of Profiled Rotor. *University Politehnica of Bucharest Scientific Bulletin, Series D: Mechanical Engineering* 70: 93-102.
 15. European Commission (2021) Energy Efficiency in Pumps and Fluid Handling Systems.
 16. Stepanoff P (2022) Energy consumption and optimization in positive displacement pumps. *Energy Engineering*.
 17. Singh B (2023) Energy-Efficient Pumping Systems: Review of Technologies and Performance Metrics. *Renewable Energy & Power Quality*.
 18. Li J (2024) Low-Power Operation of Displacement Ventilators Using Novel Rotor Architectures. *Energy Reports*.
 19. ASME Energy Systems Division (2023) Advances in High-Efficiency Fluid Machinery. ASME.