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# NEW POTENTIAL OF OLD WANKEL-TYPE MACHINES

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**Topics**
- Technologies and infrastructure for sustainable mobility (1)
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## Abstract

One must acknowledge that epitrochoidal machines with circularly moving evolvent gear systems (e.g., Wankel-type machines) are indeed ingenious.

Is it possible that such mathematical beauty cannot deliver corresponding utility in market-relevant applications?

I will discuss the potential of bi-angular piston machines and circularly moving evolvent gear systems in applied mechanics.

Bi-angular machines have some important advantages.

- First, the compression ratio is defined by design and not limited by the geometry. This makes it possible to employ the more efficient Diesel process in such machines.
- Second, the vibration resonance of the rotating piston can be suppressed in contrast to the classical triangular Wankel machine. This contributes to significantly less wear and tear of the working chamber.
- “Classical” reciprocating and rotating piston machines can also profit from advantages developed through new perspectives on Wankel-type machines.

One could say that all this is well known and simply ancient history. Granted. But perhaps we can develop new solutions to old problems by viewing and discussing them from a different perspective.

## 1. Rotation machines, their geometry and topology

It would be a truism to state that reciprocating piston engines dominate the power train market because, overall, they exhibit an incomparble efficiency. Nonetheless, even the fathers of today's energy technologies, such as Watt, Carnot and many others, attempted to combine the advantages of rotary motion with the efficiency of reciprocating piston machines. The famous book by *Harding*, published in 1911, contains descriptions of over 3,000 rotary machInes. *Ramelli* developed a rotary compressor already in 1588.

I, too, devoted 15 years to this endeavor. And I was successful, developing the RKM technology, *Schapiro*, in which the piston's rotary motion worked with the same efficiency as reciprocating piston machines, at least theoretically. To achieve this, the RKM piston had to rotate about a periodically jumping, instantaneous axis of rotation. Mathematical analysis of this machine proved that it belongs to the same topological class as classic reciprocating piston machines. This explains why the topologically defined characteristics of the machines should be identical with those of reciprocating piston machines. Assuming optimal utilization of thermomechanical potential, it is the topology of a machine that decisively determines its efficiency. If the advantages of rotating geometry are incorporated into the design of these machines, then, after appropriate development, the efficiency of RKM machines must be clearly superior to that of reciprocating piston machines.

While the periodically jumping, instantaneous axis of rotation contributes to a radical improvement in efficiency, it also results in a reduction of the power density of RKM machines compared with the high-speed rotating piston machines of Felix Wankel as well as turbines.

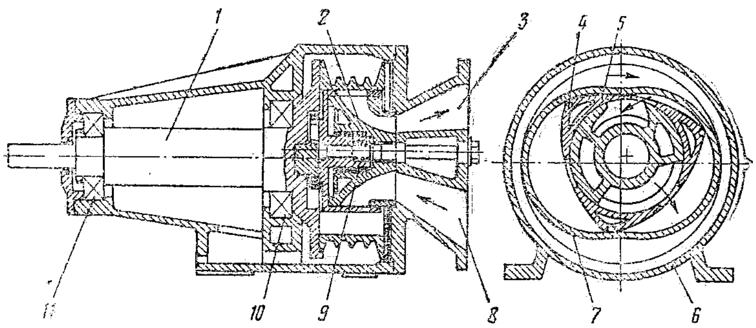


Fig. 1. Compressor, Borsig Company, Berlin 1961 (from *Ansdale*)
1 – Driveshaft; 2 – immovable insert with gas exchange channels;
3 – gas exhaust channel; 4 – radial seal; 5 – rotor; 6 – immovable housing;
7 – movable housing with working chamber; 8 – gas intake channel; 9 – rotor bearing;
10, 11 – movable housing bearing.

Turbines are world champions in power density because of their extremely high-speed rotation. However, they are truly efficient only when the turbine blades approach the speed of sound in the airstream. Turbines are not only extremely expensive but also achieve a high efficiency only in a relatively small operating range. Thus, they are generally cost-effective only for applications requiring megawatt or gigawatt output. They are unsuitable for massproduced, mobile applications for use on land and water. In these areas, the technolgy for main and supportive motors is dependent on volume displacement machines.

## 2. The Efficiency of Wankel Machines

Felix Wankel devoted his life almost exclusively to planetary piston machines, because they achieve very large volume power densities through the continuously circular motion about the instantaneous axes of their pistons, which attain exceedingly high rotation speeds (on the order of 15,000 – 20,000 rpms). On the one hand, it is sad that the exceptional work of Felix Wankel and his team has never received the market attention it deserves. Both economic-political and understandable special interests of automotive giants contributed to that. On the other hand, the deplorable efficiency of Wankel machines and their resulting excessive fuel consumption played a disastrous role. The advantage of their power density could not compensate for their disadvantages in times of energy scarcity.

There are two major reasons for the Wankel motor's low efficiency: first is the geometry chosen for the famous Wankel machine, with its Reuleaux triangle in the piston's cross section and the epitrochoidal contour of the working chamber with changing algebraic sign of curvature along the chamber contour. The classic Wankel machine's maximum possible compression is wholly defined by its geometry. This geometry limits the machine's compression ratio to a number in the range of 10. As a result, this machine can be realized as a combustion engine only when employing the Otto process and similar processes in a single compression stage. The much more efficient Diesel process requires a compression ratio no less than the range of 20. Two-stage diesel Wankel engines exist, in which one stage serves as a pre-compresssor and the other as actual motor. This approach has not proved economical as the pre-compressor devours more energy than the efficiency difference between the Otto and Diesel processes can yield.

Second, the problem of sealing the rotating piston against the chamber wall has not yet been solved satisfactorily. Compared to reciprocating piston engines with their surface-to-surface seal between piston and cylinder wall, the seal between the rotating piston and the chamber wall of the trochoidal machine is a line-to-surface seal. Trochoidal machines can be realized with $n$ orders of rotor symmetry, $n$ = 2, 3, ... The piston's spring-loaded sealing lip slides along the chamber wall at a permanently changing angle during piston rotation. This angle's amplitude is defined by the piston's order of symmetry. This amplitude is greatest at $n = 2$ and is approximately equal to $\pi$ minus the angle between the tangents to the piston's contours at the sealing point. It is approximately equal to $\frac{2}{3}\pi$. At $n = 3$ (the classic Wankel machine), the amplitude is approximately $\frac{1}{2}\pi$. Thus, it is clear why Felix Wankel chose the third order symmetry for his machine's piston – the sealing quality of this machine is roughly 30% better than that of a machine with the piston symmetry of the second order. In the following, we will devote our attention to these trochoidal machines with second order symmetry pistons (PPM2, Planetary Piston Machine with $2^{nd}$ order piston symmetry).

## 3. Planetary Piston Machines with $2^{nd}$ Order Piston Symmetry (PPM2)

Let us imagine that the sealing problem for planetary piston engines has been solved by means of an independent sealing technology. Which of the almost inifinite variety of planetary piston machines would be most interesting economically as a combustion engine?

In my opinion, given the assumption above, a planetary piston machine with 2nd order piston symmetry (PPM2) would emerge as the clear victor.

The reasons for this are simple. First, the contour of the PPM2 piston, a trochoidal arc, conforms to at least one similar arc in the contour of the working chamber. If we build a combustion chamber into the arc portion of the chamber wall that conforms to the PPM2 piston, then the machine's compression will equal the relation between the maximum volume defined by the PPM2 geometry and the geometry-independent volume of the combustion chamber. Thus, the compression of a PPM2 motor is not defined solely by the trochoidal geometry but, contrary to the Wankel machine, together with the designed size of the combustion chamber. Consequently, the PPM2 machine can definitely be designed as a one-stage diesel with concomitant significantly improved efficiency.

Second, the piston's rotation speed and, thereby, the power density of the PPM2, is limited only be the fuel's rate of combustion. That, in turn, means that the PPM2 engine should be able to achieve the maximum power density possible for any fuel used.

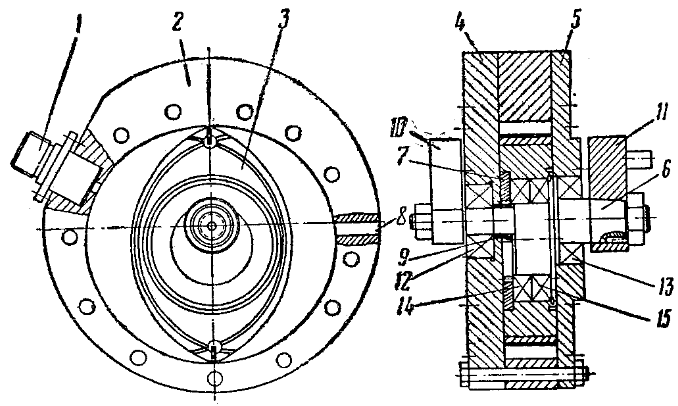


Fig. 2. Compressor RPK-160, Zhukovsky Kharkover Aeronautical Institute, Kharkov 1967 (from *Sukhomlinov*):
1 – gas exhaust valve; 2 – immovable housing;
3 – rotor; 4, 5 – facing plates; 6 – eccentric shaft;
7 – gearwheel, internal gearing; 8 – intake channel; 9 – immovable gearwheel;
10, 11 – dynamic balacing weight; 12, 13 – drive shaft bearing; 14, 15 – rotor bearing.

With PPM2 machines, I hope to maximize both efficiency and power density.

Incidentally, all the usual advantages of planetary piston machines also accrue to the PPM2 machine. Among them are:

- small, light and simple construction requiring little space,
- few moving parts with less wear,
- outstanding power density.
- dynamic balancing provides quiet and smooth operation.

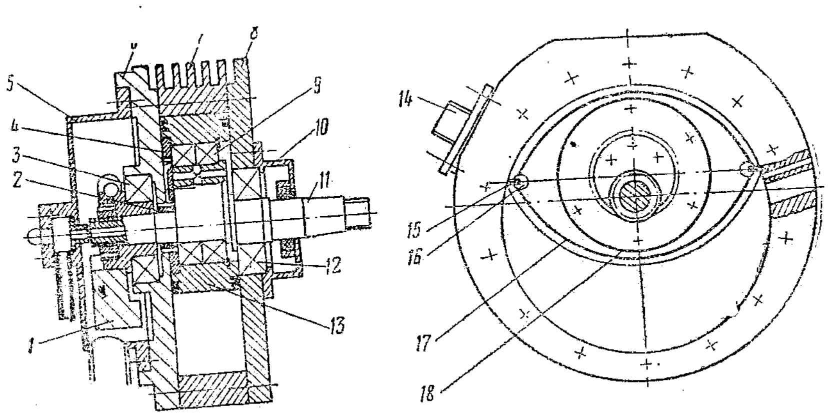

Fig 3. Compressor RPK-300, Zhukovsky Kharkover Aeronautical Institute, Kharkov 1969 (from *Sukhomlinov*):
1 – dynamic balancing weight; 2 – immovable gearwheel;
3, 12 – driveshaft bearing; 4, gearwheel, internal gearing; 5, 10 – oil capture housing;
6, 8 – facing plates; 7 – housing; 9 – rotor bearing; 11 – eccentric shaft; 13 – rotor;
14 – gas exhaust valve; 15 – sealing strip; 16 – triple point sealing element;
17 – facing plate sealing strip; 18 – oil separation ring.

## 4. Desired Qualities of a Seal

The vision developed in the previous section rests on the assumption that the planetary piston machine's well-known sealing problems can be solved. I believe I have solved this problem – although only theoretically, at the moment. The solution is based on a new composite material I have invented. This material can be used as an elastically deformable element for a seal that will adapt to every curvature.

This material has the following properties decisive for the economic efficiency of PPM2 machines:

- design of the material can set its elasticity across a extremely wide parameter range by,
- the material can be formed into almost any shape and will conform to every curvature under pressure,
- this material's reaction speed to deformation should be at least 4 x $10^5$ cm/sec. Sealing the piston with this material against the chamber wall of a PPM2 with a chamber diameter of 30 cm would theoretically allow rotation speeds of up to 240,000 rpm,
- the wear on this material should be comparable to the wear on today's sealing materials,
- its elasticity characteristics will remain virtually unchanged up to temperatures approaching 1,200 °C.

I ask for the esteemed readers' understanding that I do not disclose the know how for producing this miraculous material at this point. This know how is not yet protected, being currently in the assessment phase.

## 5. Acknowledgement

The author has the honor of thanking in special measure Karl Sittler for his furthering of this work, for his almost boundless patience, for his moral support and his help with the English version of this article.

I also thank Mr. Ivan Pyatov for his cordiality and the effort he expended in providing me with the difficult to attain information on trochoidal machines in industrial use.

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