BARM – Bi-Angular Rotation Machines –
The Trochoidal Technology Without of Drawback

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Key Topic:
Engines, Compressors, Backing vacuum pumps, Dryings pumps, External combustion engines, Internal combustion engines, Trochoidal rotation machines, Drones, Wankel motors, Clean energy turnaround, Modes in the technical development of modern society

Abstract

The fashion controls thinking think fashion designers and become billionaires. The fashion of today is the Electromobility. The technological issues in the other energy-relevant segments would be almost forgotten or neglected.

Turnaround: Everything you know about Wankel machines will be 1.5 times better for BARM machines, much more profitable and more efficient. And especially 20 times more durable.

Schapiro, B., 2011-2 introduced the BARM as an internal combustion machine, and *Schapiro, B., 2012-2* introduced the BARM as an external combustion machine. *Schapiro, B., Dunin, S., 2013* published the overview of different technical aspects of the BARM applications.

The thermodynamic description, that is the modelling of these processes, is a physical approximation valid not only for BARMs, but for all rotational volume displacement machines in similar application, for instance, in *Pyatov, I., 2010* and *Pyatov, I., Schapiro, B., 2010*.

Here I reminisce the technique in physical approximation and discuss the economic and political aspects again and new.

A. Technology and society

Fashion controls thinking, think fashion designers and become billionaires. The fashion of our time is electromobility. It is really necessary to make living in metropolitan areas bearable and to preserve nature in our cities. But fashion is fashion. The technological issues in the other energy-relevant segments are almost forgotten or neglected.

The other energy-relevant sections of our economy are much greater than in the car-application and very manifold. They include a variety of pumps, endless different compressors, high-power engines on land and sea, light aircraft, helicopters, and drones. Almost all of these applications rely on volume displacement machines.

In most of these applications, the volume displacement technology is already so morally outdated that a deep innovation of the volume-displacement machines will bring enormous economic benefits and trillions of dollar advantage to investors.

This understood many players in the economy and put on the trochoidal Wankel technology. However, this could not fulfill the hopes. These hopes can be realized with the BARM technology.

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B. Something about BARM versus Wankel as Motors

The Wankel engine has long been regarded as a cult object. Indeed it has something bountifully hypnotic beauty. Its quiet rotation, very few parts, no valves, surprisingly little weight and unexpectedly high power density, all this takes everyone who has a sense of beauty and technical progress. But on the market the Wankel motor is dead. Why?

Fig. 1. Wankel engine with open lid, somewhat obliquely photographed. Please note the contact of the seal with the inner surface of the chamber on the left. If the curvature of the side wall is positive at the contact point, then the curvature at the contact points of two other sealing elements is negative. In the places where the positive curvature changes to the negative, the centrifugal force abruptly tips over, and the sealing lip chops into the inside of the chamber like an axe. See fragment **e**) in the explanation below.

There are as usual explanations “4 reasons why the rotary engine is dead. The Wankel engine was last seen in a production car in the Mazda RX-8, and currently there are no rotary engines in production. Mazda may bring it back in the RX Vision, however there are many disadvantages to the rotary engine which has kept it from being successful.

a) Rotary engines have a low thermal efficiency as a result of a long combustion chamber and unburnt fuel making it to the exhaust. **b**) They also have problems with rotor sealing as a result of uneven temperatures in the combustion chamber since combustion only occurs in one portion of the engine. **c**) Oil consumption is also a problem, as oil is injected to add lubrication and help keep the rotor sealed. **d**) Finally, emissions are poor and fuel economy is terrible, and ultimately this is the cause of its death”, *GJGzUYCI, 2016*.

But I see the main disadvantage of Wankel machine in **e**) the 5^{th} reason: it has extremely short lifespan. The cause of this phenomenon is that the centrifugal force acting on the seal of the rapidly rotating rotor changes its direction from in-side to out-side as it the small bulge passes.

Thus, the seal strikes the body of the machine like an axe and destroys it 20 times faster than the reciprocating pistons destroy the body of the reciprocating engine. Thus, the Wankel engine drives the entire 100,000 km in the automotive application instead of the expected more than 2,000,000 km in the renowned reciprocating competition.

Everything you know about Wankel machines will be 1.5 times better for BARM machines, more profitable and more efficient. And thus 20 times more durable: **e**) BARM has no change of the curvature sign hence no kipping of the centrifugal force then no attack on the body thus no shorting of the lifespan. **d**) Emissions of BARM as an internal combustion machine will be more than good because of easy attainable high pressure in the working chamber and therefore high burning temperature and hence good fuel economy. **c**) Oil consumption will be also superbly because of labyrinth oil distribution and surface-to-surface sealing contact with the chamber walls in contrast with line-to-surface contact by Wankel motors. **b**) The temperature distribution in the BARM combustion chamber will be significantly less uneven as by Wankel thus of smaller chamber and higher power density. This together with surface-to-surface sealing solves the sealing problems well enough. **a**) Finally BARM engines will have a vastly higher thermal efficiency as a result of high pressure and short combustion chamber and it makes good conditions for well burning fuel making the almost clean exhaust.

One thing still has to be said. The Wankel machine with the triangular Reuleaux piston does not need any valves in every application. The BARMs with the two-sided piston also need no valves as pumps and compressors. But they need valves as combustion engines.

In the times of the discovery of the trochoidal geometries, so 100 years ago, the valve technology was hardly developed. Therefore, the lack of valve was a strong argument for Wankel’s decision in favor of a valveless construction.

Today the valve technology is developed as good as to perfection. Consequently, there are no longer any arguments for having to do without valves. Thus, there is no alternative to the BARM technology as rotary piston technology without disadvantages for all applications as pumps, compressors, internal and external combustion engines on land, water and air.

Under consideration that the revving limitations are by BARM 1.5 higher than by Wankel I proclaim: Everything you know about Wankel machines will be 1.5 times better for BARM machines, more profitable and more efficient. And especially 20 times more durable.

B. Precursors of BARM

Wankel machine is an epitrochoidal one, the BARM also. BARM is an abbreviation for: **B**i-**A**ngular **R**otation **M**achines. The form of the rotational piston’s cross-section as an arc-figure with two corners gives the machine its name.

The precursors of the BARM have been well known since the 1920s. To date they have been developed and deployed until now only as compressors.

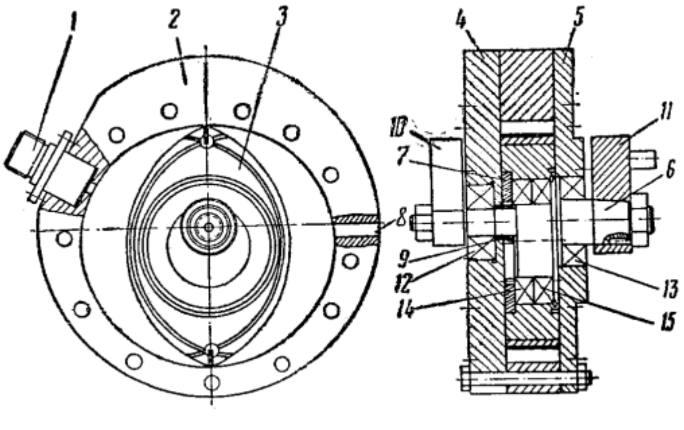

Fig. 2. A compressor developed at the N. Zhukovsky State Aerospace University "Kharkiv Aviation Institute" in the 1960s and repeatedly deployed in industry. Cited from *Sukhomlinov, R., 1975*.

Like all rotating piston machines, BARMs, too, run smoothly and quietly and have high power density. They have high power density almost 1.5 higher than Wankel machine because of the almost 1.5 higher speedy of rotation; at Wankel up to 20,000 rpm, at BARM up to 30,000 rpm.

They both have a cylindrical design which simplifies assembly and reduces the time and energy requirements for production. Only BARMs are capable of diesel operation in a single section because their smallest residual volume can theoretically be zero and the volume and location of the separate combustion chamber required for internal combustion is completely independent of the trochoidal geometry. Thus, one can generate almost any compression ratio desired with BARMs.

C. BARM as an Internal Combustion Machine, short review

BARMs employ different trochoidal chamber geometry than the classic Wankel engine. Like all rotary piston machines, power takeoff is achieved via eccentric planetary gearing. The key element here is an innovative, pendular sealing element that seals the piston surface-to-surface with the chamber walls rather than line-to-surface, as in the classic Wankel engine, *Schapiro, B., 2011-2* and *Schapiro, B., 2012-2*.

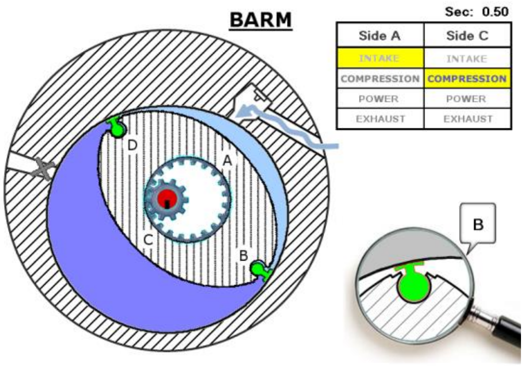

Fig. 3a

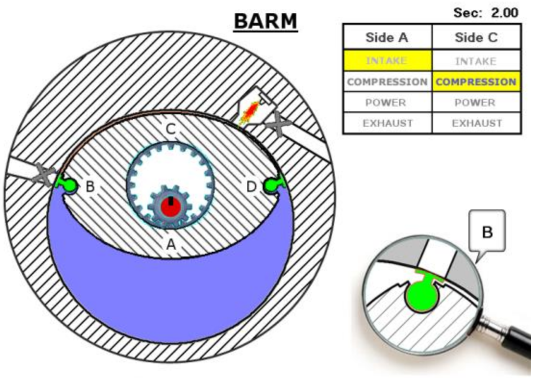

Fig. 3b

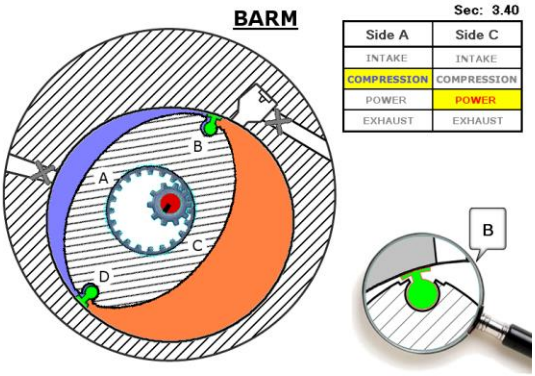

Fig. 3c

Fig. 3a-c. Schematic BARM as a 4-cycle engine. Each side of the piston works as an independent piston. Thus a single BARM power unit is equivalent to a two-piston reciprocating piston machine. Shown here are sample piston positions. Constructing a BARM with two pistons powering one drive shaft creates an engine equivalent to a four-cylinder reciprocating piston engine. Every BARM cycle in the two-unit combination is a power cycle, continuously transferring torque to the driveshaft.

The chamber contour here is not circular but rather a trochoid, an algebraic figure of the 4th order. BARMs are volume displacement machines capable of deployment in all relevant areas. I expect their particular advantages to be evident when employed as environmentally friendly, high performance combustion engines, range extenders for electric vehicles, emergency power generators, compressors, thermosolar and geothermal engines and machines for exploiting high and medium temperature exhaust heat of all kinds.

As our thermodynamic analysis demonstrates, employing BARMs enables more efficient energy production and use than is possible with the classic Wankel engine, thereby saving energy. Let's take a look at a comparison between reciprocating piston and BARM engines, both in diesel versions.

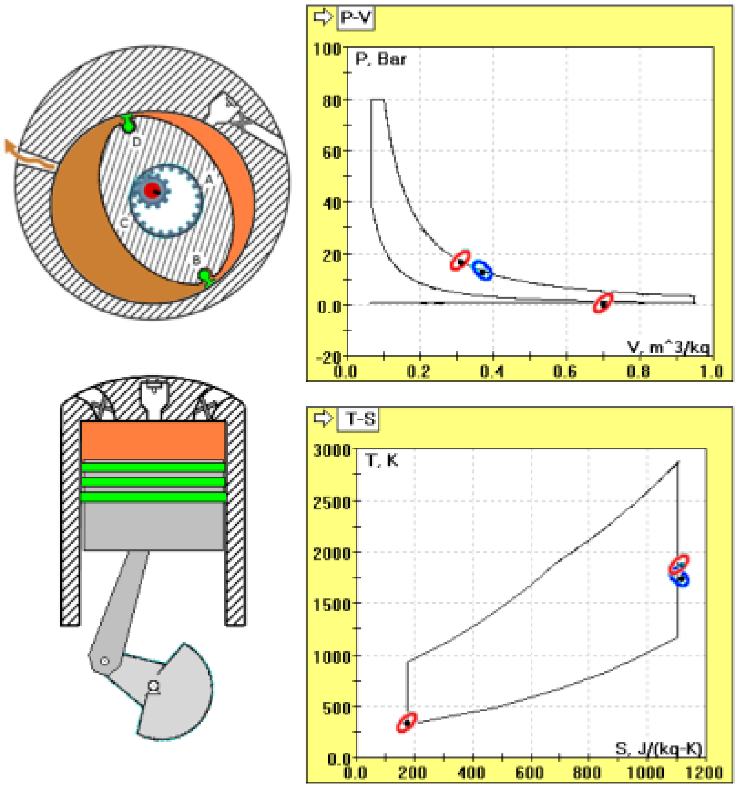

Fig. 4a

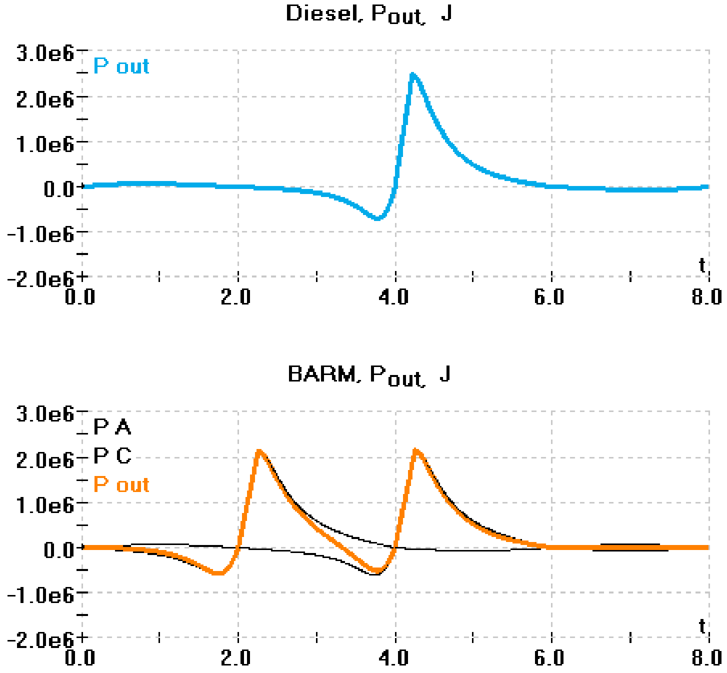

Fig. 4b

Fig. 4a-b shows a thermodynamic simulation approximating non-deformable piston and housing as well as a working medium with no viscosity. The blue point and blue curves corresponds to the reciprocating machine, and the red one to the BARM. The work cycle is on side A of both the BARM and the reciprocating piston. The points in the red, right-leaning ovals in the state diagram mark the thermodynamic state on sides A and C of the BARM piston. The concomitant state is marked by the point in the left-leaning, blue oval for the reciprocating piston.

In this simulation, both the reciprocating piston and BARM machines run a diesel process. They have the same working volume, the same cycle start and end pressures, the same cycle length, “burn” the same amount of fuel per cycle and piston side and, of course, deliver the same energy efficiency under these conditions, namely, 56%.

Under these conditions, the BARM delivers almost twice as much power per cycle compared to the reciprocating piston engine because both sides of its piston work. It is important to note that – seen cinematically – the BARM piston can turn faster by a factor of almost 4 than can the crankshaft of the reciprocating piston machine under otherwise comparable conditions.

If this simulation corresponded to reality, an increase in power density by a factor of 8 (2 x 4 = 8) could be theoretically expected. I think that BARM combustion engines will actually have a three to occasionally five times higher power density than reciprocating piston engines with the same working volume. Thus I expect that a BARM engine can achieve equivalent performance and equal exhaust gas quality as a reciprocating piston engine with but 20% – 30% of the latter’s size and weight!

Material for the engines as well as energy for production is also conserved because of the high BARM power density. There exist sufficient heat and pressure resistant – materials, such as metaloceramics, silicon carbide and other ceramic materials to withstand the high combustion chamber temperatures, *Kriegesmann, J., 2005*.

In the state diagram Fig 4a, the blue point passes the orange point and then the orange passes the blue, so they complete each cycle in the same time.

The graphic in Fig. 4b shows the comparison of the simulated performance over time, blue for the diesel reciprocating piston and orange for the BARM. Performance is negative at certain points because the machines use energy for moving the pistons and compressing the air. Significantly more energy is won; however, because burning releases the stored chemical energy and both engines convert this energy into usable power driving the driveshaft or crankshaft respectively.

BARM combustion engine CO_2 emissions will be in the same range as that of reciprocating engines as and significantly less than the Wankel engine's due to the higher efficiency of BARMs.

The problem with NO_X emissions is the same as it is for reciprocating piston engines.

Competing technologies. Both reciprocating piston engines with their efficiency and classic Wankel engines with their power density compete in this arena. BARM and other rotating piston engines offer the same advantages in the 2 kW to 10 MW power range and thus have a competitive advantage in the technology and industrial markets.

BARM does not compete with gas turbines since turbines are usually highly effective in power ranges above 10 MW.

D. BARM-Utilization as heat engines, external combustion machine

Heat engines with cyclically regenerative working media, or external combustion machines, do not use chemically stored energy internally to produce mechanical power. They use an externally produced temperature difference, hence, the name external combustion machine. They produce mechanical power by transferring heat from a hot site to a cold site in such a way that part of the heat can produce useful mechanical power. Such machines employ a working medium, usually gaseous, that is cycled back and forth between the heater and the cooler.

We wish to use BARMs as heat engines, not only to capture and exploit the waste heat from industry and municipalities but also for power generation using nature's free energy sources, especially thermosolar.

D1. General Remarks Concerning Heat Utilization

One of the most promising uses of BARM machines is for transforming heat to mechanical power. That is, anywhere there is a heat source available with a working medium between 400 °C and 1,200 °C of sufficient capacity to deliver between 10 kW and 10 MW of heat energy.

This encompasses a wide variety of industrial waste heat sources, such as waste steam and exhausts gases and the burning of flammable waste gases, as well as focused solar heat and thermal output of geothermal sources. Our rough estimate of the total annual potential of all industrial and municipal waste heat is in the range of 1,000,000 GWh, approximately one-fourth of world energy requirements today.

Currently, there exists no technical standard with satisfactory efficiency to utilize the heat available from these sources.

The highly efficient turbine technology is advantageous only in the multiple megawatt power range. At present, the best alternative for heat utilization in the low and medium power range is the Stirling engine. Therefore, we wish to compete with the Stirling engine.

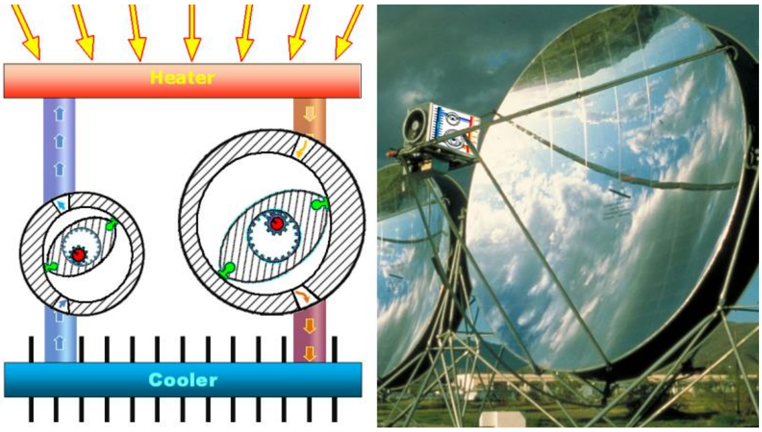

Fig. 5. The larger machine on the sketch's right is an expander, that is, a motor. The smaller machine on the left is a compressor. The working medium could be helium, for example, or another medium. Both machines are laid out such that their power shafts turn at the same speed. Thus both motor and compressor can be mounted on the same shaft which also drives the generator and a cooling fan. With this layout, the machine almost has but a single moving part with a complicated form, namely two pistons, permanently geared to a single power shaft.

D2. Stirling and other ideal cyclical processes

It is generally well known that no heat engine can surpass the efficiency of a Carnot machine embodying the ideal Carnot cyclical process.

It is less well known that a number of other thermodynamic cyclical processes can exhibit the same coefficient of efficiency $\boldsymbol{\eta}$ as the Carnot process under ideal conditions. Among these are the Stirling cyclical process especially and, under a few specific conditions, the Rankin process with $\boldsymbol{\eta}_{\text{ideal}} = (\boldsymbol{T}_{\text{heater}} - \boldsymbol{T}_{\text{cooler}}) / \boldsymbol{T}_{\text{heater}} = 1 - \boldsymbol{T}_{\text{cooler}} / \boldsymbol{T}_{\text{heater}}$.

But not many know that both the Carnot engine and the equivalent Stirling engine perform at maximum efficiency zero power. Therefore, not the highest efficiency in itself is important, but the efficiency at maximum of the power performance. In our case it will be given with the Brayton-Joule (B-J) process, $\boldsymbol{\eta}_{\text{B-J}} = [\boldsymbol{1} - \sqrt{(\boldsymbol{T}_{\text{cooler}} / \boldsymbol{T}_{\text{heater}})}]$.

So I focus primarily on the Brayton-Joule process. I will show that, as a precursor to our design, it is the best fit to our design for technical and economic reasons. With current technology, the Rankin and Brayton-Joule processes are realized with turbines which exhibit an acceptable efficiency only in the multiple megawatt range. Until now, the Stirling process was the only one employing the principle of volume displacement and implemented with a reciprocating piston engine.

The efficiency of an actual Stirling engine depends on how closely the real process can be made to approach the ideal. The same holds true, of course, for the other cyclical processes, this also holds true for our *Schapiro, B., Dunin, S., 2013* modification of the Brayton-Joule process.

D3. BARM versus Stirling engine

The BARM volume displacement heat engine realizes a new cyclical process we developed together with Prof. Sergey Dunin. It is most closely related to the Brayton-Joule cyclical process.

Even in an ideal representation, the BARM heat engine does not achieve Carnot ideal efficiency. But since when is our world ideal? Only our beloved wives!

So, the future for BARM and for the Stirling engine as heat engines depends entirely on the extent to which technical realization can minimize variance from the ideal. In this respect especially, we consider the BARM competitive with the Stirling engine for the following reasons:

- The BARM has a significantly higher power density that the reciprocating piston Stirling engine. Consequently, its compact architecture.
- With distinctly fewer moving parts, the BARM must be not only smaller, lighter and more economical to produce, but also much more reliable than the Stirling engine.
- While we expect very similar friction losses in the working chamber and conduits of both engines, we expect notably less friction losses in the power shaft and bearing mechanics.
- And most importantly – under realistic conditions, that is, with a heat regenerator, BARMs will deliver higher efficiency than Stirling engines at the same maximized power.

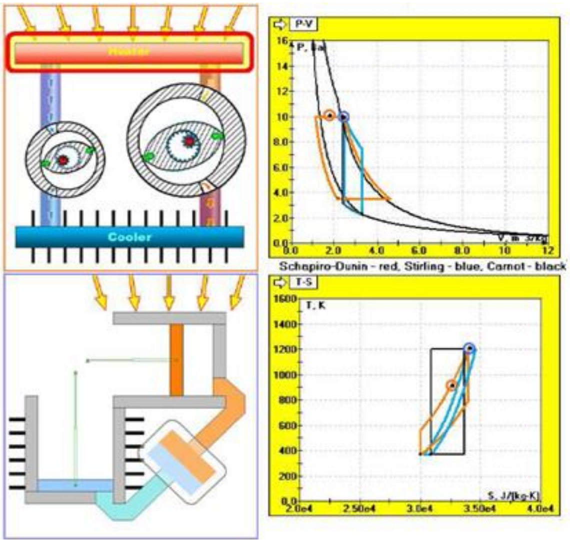

Fig. 6 shows a thermodynamic comparison between a substantially idealized (although not ideal while without heat regenerator) Stirling engine and an only slightly idealized BARM. The BARM's superior efficiency is obvious. Of course we examined this comparison over the entire relevant power spectrum. The results are not shown here because the comparison really makes sense only when a heat regenerator, that is, a heat exchanger, is incorporated.

D4. The role of the regenerator and heat exchanger, respectively

The comparison in Fig. 6 was made without employing a regenerator for either engine.

The regenerator idea consists of separating the heat path from the mass of the working medium. With the help of a heat exchanger, one can return a portion of the heat remaining after the power phase to the working medium after the cooling phase. Thus the thermodynamic losses due to irreversible cooling can be minimized.

But the irreversible losses in the Stirling engine seem to be greater than those in the BARM heat engine. That is associated with the typical efficiency of the Stirling engine's heat regenerator, generally in the 60% range, *Fette, P., 2012*. The efficiency factor of industrial heat exchangers that can be employed with the BARM is approximately 95%, *Jüttemann, H., 2001*. Therefore, we expect that, in reality, BARMs with heat exchangers will outperform today's almost perfected Stirling engines. The relationship of both machines overall efficiency factors will, of course, depend on the output load.

The comparison of overall efficiency is made under thermodynamically equal conditions. The working medium in both engines is He_2 with a mass of 100 g, the maximum volumes of the working chambers are equal, as are the maximum and minimum temperatures, 1,200 °K and 400 °K respectively. For the simulation, we assumed an exaggerated efficiency factor of 70% (blue circlets) for the thermal efficiency of the Stirling engine's heat regenerator and 90% (red squares) for the BARM's heat exchanger. Losses due to mechanical friction and viscosity of the working medium were not incorporated for either engine.

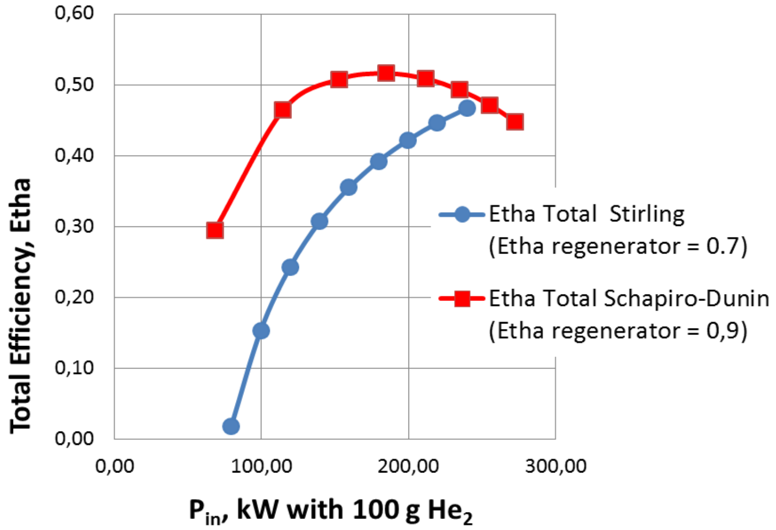

Fig. 7. The computer-simulated total efficiency factor **η** of the Stirling engine versus BARM, with thermal input $\mathbf{P_{in}}$ in kW, an exaggerated efficiency factor of 70% for the Stirling engine's heat regenerator (blue circlets) and 90% (red squares) for the BARM's heat exchanger, the same 100 g He_2 as working medium for both engines, a maximum temperature of 1,200 °K and a minimum of 400 °K.

The ends of the curves in Fig. 7 to the right and left of the graph mark the position where thermodynamic utilization is no longer possible. The Stirling engine's efficiency increases monotonically until reaching its maximum value, at which point the working medium can no longer take up heat and thermodynamic function collapses.

The overall efficiency factor of the BARM with a 90% efficient heat exchanger reaches a maximum of 52% with an energy input of approximately 180 kW. That is around 12% more than the idealized Stirling engine's overall efficiency and around 18% better than the overall efficiency of the best Stirling engine currently in use, namely 34%. Two demonstration models of the BARM exist currently, but no practically tested prototype.

If there is interest in lower power applications, e.g., for decentralized power supply, one can reduce the mass of the working medium. Thus one could achieve approximately the same overall BARM efficiency with but 1 g He_2 and energy input of 1.8 kW, theoretically resulting in 1 kW energy output. Of particular interest is the BARM's equation of state, resulting in a maximum pressure of 10 bars and a minimum pressure of 3.8 bars. That should result in prodigious reliability and extended service life for the engine. The same holds for the Stirling engine, of course. Thanks to the still valid Boyle & Mariotte law, one can minimize the dimensions of both machines inversely proportional to desired pressure.

Competing Technologies. Stirling engines are one of the technologies competing for thermosolar use and heat recapture. The picture in Fig. 5 shows a dish Stirling engine, part of a thermosolar pilot project by the firm SOLO in Spain. We have pasted in a schematic of our BARM to show the potential. Stirling Energy Systems, a US company, achieved world-record efficiency for Stirling engines of 31.25% in 2008. Nonetheless, it was forced to declare bankruptcy in 2011.

Summary: Uses as thermosolar power plants and for heat recapture

- We believe BARMs can be successful in commercial heat utilization in the medium temperature range, such as industrial waste heat recapture and geothermal power plants.
- Stirling engines are better than BARMs in the low temperature range. However, there is insufficient commercial potential in this range to warrant great effort in this area, except perhaps as a hobby.
- We expect a clear victory for BARMs in the high temperature range, particular with thermosolar power plants.

Nota bene: Solar batteries

We do not consider nor compare external combustion BARM with solar batteries here because external combustion BARM works from the heat flow whereas solar batteries work from solar beams, especially from high energy (high frequency) part of them.

E. Synopsis

After intensive and wide-ranging study, our conclusions are:

E1. External combustion machines, e.g. for thermosolar energy production

E1.a As a trochoidal rotating piston machine, BARM's advantages are higher power density with concomitant smaller dimensions and significantly less weight. BARM's high rotation rate means that its power density is limited only by the rate of temperature increase and the viscosity of the working medium.

E1.b In contrast to the well-known Wankel engine, trochoidal BARMs will have a very long service life. The reasons for this are described in Section **B.e**).

E1.c BARMs with heat exchangers are particularly interesting in the high temperature range around 1,000 °C, where they can achieve the same efficiency – slightly more than 40% (optimistic estimate: up to 45%) – as other volume displacement engines under realistic conditions.

E1.d The external combustion BARM gains a small efficiency advantage from the fact that, from its starting position, the BARM piston opens the crescent-shaped working volume more slowly than a reciprocating piston (both compared at the point of minimal volume). Compared with other common geometries, this lengthens the isochoric pressure increase phase, thus improving efficiency slightly.

E1.e A further advantage is the BARM's simple construction which, along with the lighter weight, promises lower production costs and longer service life.

The expectation that external combustion BARMs will produce only slightly higher efficiency than other volume displacement machines relates to the fact that theory predicts the efficiency factor's dome-shaped dependence on the pressure relationship with a maximum in the range of P_{max}/P_{min} from 8 to 10 for the more powerful high temperature version. Thus, the real strength of volume displacement engines, namely their ability to create large pressure differentials, cannot contribute to increasing efficiency in thermosolar applications. Nonetheless, BARMs can contribute significantly to increasing power density as well as lowering production costs.

E2. Internal combustion engines for motorized energy production

As internal combustion engines, BARMs can, in principle, actualize every known cyclical process. The Diesel or Atkinson cycles are especially attractive. We believe that internal combustion BARMs offer the most advantageous combination of high power density, good efficiency, low noise level and affordable production costs.

E2.a High power density is typical of all trochoidal rotating piston engines. High rotation speed is the best known advantage of the Wankel engine with the resulting power density. The same holds true in full measure for BARMs.

E2.b BARMs will have a very long service life. The principle difference from the Wankel engine is the long service life of BARMs.

The Wankel engine's short service life is not caused, as many believe, by deterioration through wear of the sealing lips. The sealing lips are expendable parts, easily replaced regularly. The short service life results primarily from damage to the interior of the chamber caused by the unavoidable resonance of the sealing lip oscillation due to the high rotation frequency and the tip over of the centrifugal force vector.

The fundamental geometric cause of the sealing lip's impact on the chamber wall is due to the inner contours of the Wankel engine's chamber which has both concave and also convex (or at least not concave) stretches. Strong centrifugal forces act on the sealing lips when they slide off the contour very quickly. These forces change their direction during the transition from a concave to a convex stretch and again from convex to concave. The change of centrifugal force direction, amplified by the resonance, hammers deep grooves into the interior wall of the working chamber. These grooves thus appear as though they had been hacked in with an axe.

This damage to the interior chamber wall is the real cause of the Wankel engine's short service life. Mazda's RX Wankel engine set a world record of about 150,000 kilometer equivalents on the test stand. The service life of a good Mercedes or Peugeot reciprocating piston diesel engine exceeds 2,000,000 kilometers in a vehicle.

The BARM engine's inner chamber wall is very close to a circle in cross-section, that is, only concave, and the curvature of the chamber changes little by little, only gradually and minimally. Thus, changes of direction or quick changes in the sealing lip's centrifugal force cannot occur and damage to the interior chamber wall à la Wankel is never a problem.

Therefore, we expect BARMs to have a long service life, certainly not less than that of the classic reciprocating piston engines.

E2.c We attribute the BARMs good efficiency as volume displacement, internal combustion engines to the fact that their efficiency's dependence both on the temperature differential $\Delta T/T_{Burn}$ as well as on the pressure ratio P_{max}/P_{min} (and also the compression ratio) always increases monotonically. Thus, volume displacement engines can really take advantage of their strength, namely the ability to develop great pressure differentials, to increase efficiency.

At a burn temperature of 2,000 °C, exhaust gas temperature of 550 °C and a compression ratio of 24:1, diesel BARMs could theoretically deliver full load efficiency of about 60%, without considering potential increases via a turbocharger, for example, or other devices. The expected power to weight ratio would be under 1.0 kg/kW (compare: Otto engines 2-5 kg/kW, diesel engines 5-6 kg/kW).

E2.d We attribute the low noise level to the design's lack of piston rods and crankshaft which are a major contributing factor to the noise levels produced by reciprocating piston engines. Further, noise producing tensions in the motor can, for the most part, be compensated for by the centrally symmetric disposition of the working units, as shown, *Schapiro B., 2011-2*.

E2.e We expect affordable production costs due in particular to the increased power density (less material per performance kilowatt) and the resulting power to weight ratio of 0.5 to 1.0 kg/kW, as well as fewer parts and a production-friendly cylindrical construction, similar to the Wankel engine.

E2.f Because of all these characteristics, we consider BARMs particularly suited for light aircraft engines, low to medium weight helicopters and drones, among others.

E3. Economic and political aspects

BARM provides the potential for a true energy transition both as an internal combustion engine, providing high power density with the same efficiency as reciprocating piston engines, and as an external combustion machine with higher efficiency and power density than Stirling engines.

BARM technology can be deployed anywhere, enabling decentralized and diversified energy production between 10 to 30 kW, tailored to the actual needs and sites where it is in fact utilized. This can be realized with the low weight, inexpensive production and small dimensions of BARM engines. If a BARM engine were working on every building and in every industrial facility, one could truly speak of a sustainable and not only seemingly "cost free" energy transition.

The costs of a "sustainable" energy transition in the EEG sense tax even successful and productive economies (EEG, Erneuerbare-Energien-Gesetz = Renewable Energy Sources Act). The German energy management system is not suited for worldwide utilization in any case. BARM technology would be effective worldwide: using BARM engines rather than outdated diesel generators is resource-saving and sustainable energy production.

The political potential of BARM technology:

- Conversion of the energy economy. The difference between the economic and political price of energy displays alarming aberrations. On the bourse, a kilowatt hour costs 3.8 cents today. For us, the small end-user, it costs 28.6 cents.
- Avoid the expected financial costs of the transition to supposedly "cost free" energy that already weigh on our entire economy and each individual. These include the costs for disposing of nuclear wastes, disassembled reactors and the construction of new megaconduits for electricity transport.
- Avoid the political costs to be expected with implementation of the megaconduits over the protests of directly affected local residents with a new distribution philosophy.
- Ease the overall political situation by reducing the fear of the centralized omnipotence of the energy concerns and the political impotence of governmental agencies in the energy sector. Instead, build trust and solidarity in the population by granting localities responsibility for their own energy production.
- Prevent the occurrence of extreme worst cases with individually configured energy production facilities for small user entities.

The introduction of a truly new technology such as the BARM technology can induce, finally, desperately needed innovation in the energy economy. BARM enables the conversion of an overpriced, overly complex and thus unmanageable, failure-prone energy production system to a technically easily managed, simple and economical energy production system.

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List of illustrations on the Internet:

BARM Internal combustion engine:

BARM Basic model
http://www.youtube.com/watch?v=LKN383NG-GI

BARM almost without Vibrations
http://www.youtube.com/watch?v=h0PBrjkfsb8

Thermodynamics BARM vs Back and Forth Diesel Version, identical efficiency factor
http://www.youtube.com/watch?v=Z2_2pNU1nK4

BARM External combustion engine:

BARM Schapiro Dunin Cycle
http://www.youtube.com/watch?v=iDV0KKbCQ-s

Thermodynamics Schapiro Dunin without heat exchanger
http://www.youtube.com/watch?v=UuT2o9QLLjE

Thermodynamics Stirling Cycle without of heat recuperation
http://www.youtube.com/watch?v=oz7-NWhVpe0

Thermodynamics Stirling vs Schapiro Dunin both without of heat recuperation
http://www.youtube.com/watch?v=Xu79Cce3Ji8

BARM Schapiro Dunin Cycle with Photo
http://www.youtube.com/watch?v=xAXAmiUbyUU