Project: SUSTAINABLE REVOLUTION PART 2

Further studies and technical research of the powerful sustainable Green Revolution Energy Converter (GREC) motor concept, that promises crucial climate-positive adjustable clean energy production.

Background

We are all very well aware of the biggest challenge our world faces today - climate change. While governments are slowly discussing and negotiating climate deals, it's more important than ever that solutions presented by disruptive innovation companies are put to the table. nilsinside AB presents the GREC, a highly scalable, powerful, adjustable, low cost and zero carbon emission concept which makes it an outstanding competitive solution that will affect how fast we will reach the goal of limiting global warming to 1.5 degrees.

nilsinside AB is an innovative technology start up company developing a powerful sustainable motor of the future – the Green Revolution Energy Converter (GREC).
This heat engine can transform low temperature gradients (temperature differences) into power and has a wide range of applications with potential to replace today's polluting combustion engines.

Today's external heat engines are very limited in power due to limited (small) cylinder volumes. Despite a history of over 200 years, external thermal engines, like the traditional Stirling engine, are still rarely more powerful than a lawnmower or a motorbike, with a poor volumetric scaling in relation to the delivered power. Theoretically the GREC can be compared to a Stirling engine (which alternately heats and cools a closed working volume and converts the pressure / volume changes to work) but the GREC is not limited in power.
It's difficult to compare the GREC with existing technology because external heat engines have never been built in this way before.

nilsinside's technology innovation is unique and the Intellectual Property associated with the GREC model has been approved in Sweden, China, USA and several European countries.

Project background

In spring 2022, 5 students from the Department of Management and Engineering, Applied Thermodynamics and Fluid Mechanics at the University of Linköping did a 7 week full time project on the GREC and successfully published their result:
'Theoretical Proof Of Concept For The Green Revolution Energy Converter:
Development of a mathematical model, material analysis and physical model improvements.'
In the following text, we will refer to this study as "the Report".

The University project verified the GREC technology concept based on well known established foundations of credible and reliable knowledge in thermodynamics and fluid mechanics. In addition, a new basis was laid on dimensioning and power calculations for the GREC. The Carnot's theorem applies (as for all thermal engines) so the temperature difference between the two heat storages hot and cold is crucial. Temperature differences from only 100°C up to 500°C were studied with both different engine volumes and revolution speeds. The mathematical model used to produce realistic results in terms of performance was formed by stating necessary thermodynamic assumptions, equations and simplifications that focused on the heat transfer within the engine and it was executed in MATLAB. The more pressure pulses the GREC ”Work Generating Volume” (WGV) can deliver per unit of time, the more energy, so the study dives deep into how the heat transfer is affected by the revolving speed of the WGV. When studying the heat transfer at this level then the behaviour of the "Heat Transfer Coefficient" (HTC) becomes very interesting. An advantageous HTC was observed when the revolution speed was high enough for a turbulent flow in the WGV but with maintained laminar flow in the rest of the total volume (mainly between the "Revolving Shutter” and the heat conducting fins). The more turbulence in the WGV, the better

HTC and thus more power. In fact, the GREC is adjustable just like the engine of a car. You start when you need it and regulate speed according to the situation.

The study shows that the GREC is scalable and interestingly indicates that it becomes even more efficient at larger volumes. Future research may point out "sweet spots" for different total volume sizes, temperature differences, revolution speeds and different WGV fluids.

An initial material analysis focused on performing thermal and stress simulations on selected parts and construction improvements of crucial parts for future physical models. The study also pinpointed construction improvements using Six Sigma across the existing physical model (Lab Model v2) which will contribute to the development of future GREC physical models.

The physical 'Lab Model v2' didn't work as expected after the transportation from France. Lab Model v2 should have provided ”in-situ” measurement values to compare and adjust with the theoretical calculations of parameters such as the HTC but no useful data from experiments was obtained. However, it served as a good base for material and concept discussion. nilsinside AB is working to rectify the model in order to give helpful data input but as there is no guarantee in retrieving this. Hence, the second phase of the project will continue to work with mathematical models.

Project goal

Bearing in mind this project-work (autumn 2022) will be brought forward for a continuous collaboration with LiU-student projects, the goal is to build a functioning Lab Model v3 or prototype which can be used for research and/or showcase at a later stage. The goal of this project-work is to designs and drawings that can be used for research, prototypes and industrial assembly. Also, completing a cost analysis of the GREC and a market analysis of industries and key applications for the GREC, partnering up with industrials willing to invest in prototype applications within their market sectors. The GREC is a nilsinside AB invention to deliver a scalable, controllable, emission free, power production.

The nilsinside ultimate goal is high but achievable; using the GREC to incentivise an affordable clean green energy revolution, taking part in solving climate change and driving economic growth through industry innovation. The purpose of the GREC is to generate renewable energy, worldwide, across many applications and without emitting any harmful emissions or using rare metals or non-renewable materials. We are aware this will need several research projects over time to get the project to this stage. The good news is we are already on a steady path toward this goal!

The second stage of the project, autumn 2022, will include further technical research of the full heat exchange mechanism, the energy efficiency as well as construction and material studies that will result in further mathematical model extensions and simulations regarding the dimensioning of the GREC power output. This will deliver a detailed specification (size, design, components...) of a next step prototype at this stage called the Lab Model v3, in order to prepare for a build of Lab Model v3 in the spring of 2023.

The aim is to present a better understanding of the internal heat exchange mechanism, laminar breakup, WGV-swirl, conducting fin caching, etc. and this will in turn also open up for evaluation of future possible external heat exchange connections, ”the fuel pipes”. This work will unlock new large unexplored competence fields on how to connect or interface existing heat storages for the hot and the cold side of the GREC.

The goal is to develop a scalable design that can be ”calculated” for lots of different applications. The size of the GREC-motor could be calculated from a temperature gradient and a wanted power output. Another goal is to establish a comparison study in terms of costs (manufacturing cost, CO_2 and electricity savings etc.) with existing solutions as well as to provide a first market analysis. The work would enable to advance the Technology Readiness Level (TRL) of the GREC in the direction towards a higher level. The GREC engine aims at being climate positive, now you can be part of delivering specific research to get it done.

Proposed work

The proposed work is suitable for a group of students working together, with theoretical experience within thermodynamics and fluid mechanics.

Note: Data from the existing Lab Model v2 would accelerate the research and deliver verified answers to important fundamental questions but it's a fragile unreliable device. Therefore, the project can not rely on getting the existing Lab Model v2 to deliver results during this project. However, nilsinside is currently working on it in order to get it functioning and will bring it to the University to help the project group understand the GREC concept.
The work will involve to implement further research, based on the GREC study (the report) that was done at the Linköping University in spring 2022, including:

1) Energy extraction component

Explore different means of energy output from the GREC and decide type of piston or other means used to showcase the power output :

- a simple form of power outlet from a Lab Model or a prototype can be a piston or a diaphragm connected to a linear generator. Easy to measure, build and connect,
- evaluate other means to deliver the power from the GREC,

It would be worth exploring "moving boundary" features and limits, how its area matters for different volumes at different temperature spans and different frequencies:

- designing a moving boundary and/or exploring existing solutions (membrane, piston, etc…)
- designing a simple linear generator and/or explore existing generator solutions that fits with the chosen type of 'moving boundary',

Generally, the GREC power output is adjustable just like the engine in a car, but the power curve (torque/frequency) has a much longer speed register. The goal is to prove the validity of this in the case of connecting a linear generator for electricity. This can be done by discerning 5 parts along the x-axis of the power curve:

1) origo = stationary. The electric motor turning the Revolving Shutter (RS) is in a standstill. No power is delivered,

2) laminar flow in the entire volume. The electric motor has started the RS in a slow speed without any Raynolds in the system (laminar flow in both dead volume and WGV),

3) laminar flow in dead volume with turbulent flow in WGV. The RS is in a productive speed range,

4) turbulent flow in the entire volume. The RS generates turbulence even in the dead volume and changes the inclination of the power curve,

5) "stalling" i.e. the heat transfer does not have enough time to develop so the engine stalls and there will be no power output even though the RS continues to revolve at a high rpm,

0) "stalling" i.e. the heat transfer takes place according to cases 2 – 5 but the power output is too low to activate the moving boundary. The power demand is too high for the load of the moving boundary even though the RS is easily turning at its desired rpm.

If the cases above are applicable, then applications that use free heat reservoirs with a lower temperature difference would perhaps aim for "sweet spots" within area 3, eg. "two different simultaneous fluid flows in the total volume"?

2) External heat exchange

Determine the external heat exchanges involves:

- how to connect/interface the heating/cooling from the external thermal sources/storages,
- studying why different applications need different connection types (medium, heat transfer point…) with the help of different application types (eg. liquid or gas is allowed to circulate into closed channels inside "convective fins" on one side while the other side connects directly to the surface of the source...)

Other questions to be answered:

- are there applications that can interface directly (eg. heat transfer point) or will a transfer medium (liquid or gas) be obligatory?
- will transfer media circulate in closed channels inside the "convective fins"?
- how to connect the heat from different sources such as; fuel-cells in a truck? sludge? a refrigerant in a (nuclear) power plant? steelworks or a steel mill? an aluminium factory? a bakery? a computer hall? etc…

3) Material choice refinement

Further study the finding from the report which material is to be used for each individual component (i.e., the revolving shutter, conducting fins, insulation fins, end plates and the shaft and ball bearings etc.) based on cost versus material properties (e.g., heat conductivity, elasticity, insulation). Availability and environmental impact of the materials must be taken into account.

4) Internal HTC improvement

Determine the internal heat exchanges focusing on HTC and study the :

- HTC inside the GREC, studying vertical segments of the WGV,
- effects of laminar breakers (like proposed threaded bars as counterweight...)
- surface structure / shape and colour (radiation) of the conductive fins and
- surface structure / shape and colour of the Revolving Shutter (RS),
- WGV-swirl, centrifugal force within the WGV, periferic brake...
- time-bound heat buffer effect of the conductive fins...

In the recent report the mathematical model shows and explains the importance of the GREC feature with the possibility of two different simultaneous flows of the fluid in the total volume:

1. a laminar flow in a "passive" volume between the RS and the conducting and neutral fins, breaking up into -
2. a turbulent flow with high HTC values in the WGV

The report shows a clear trend how these two different flows relate to the RS speed.
It would be of very high interest to understand:

- *the "Swirl" and how much, these values may be affected by the WGV "swirl" that appears in CFD simulations (ref TotalSim)*
- *the laminar breaker provoking turbulence.*

The Lab Model v2 now has a counterweight in form of four threaded rods mounted from side to side within the WGV opening of the RS. These counterweight rods serve two purposes;

- enable it to revolve smoothly at decent speeds without too much vibrating centrifugal force.
- breaking up the laminar flow from the dead volume starting at a lower rpm resulting in a more vivid turbulence even at lower speeds.

5) Scaling / Size

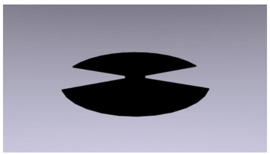
Dimensioning of the GREC while scaling the concept. How much energy do we get from different GREC motors, depending on available applications, by exercising the variables: size, temperature difference, heat/cold availability, fluid used and revolving speed.

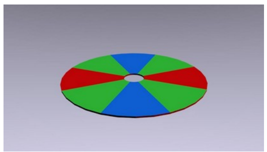
- Size: meditate on the smartest strategy for the upcoming spring project. Build a large or a small model or build both of them and compare performance?
- Reflection from the report: Tables 11,12, 14 & 20 net power output and the input added to the WGV will probably become even better if the thickness of the conducting and insulating fins were scaled (still keeping the height (thickness) of the RS and the height of the shells constant as this still ensures a constant dead volume height).

- Establish mathematical models: Separate runs to fork some values on the proportions of thickness of the dead volume... should it be reconsidered to be larger? How does the optimum vary with different fluids?

6) Revolving Shutter (RS) Design

Study alternative of 1/4 or 2/8 opening for the WGV.





7) Comparison with existing techniques

Establish cost calculations table of the GREC concept compared to existing energy production solutions (traditional and renewables) in terms of :

- actual over all costs (manufacturing cost eg. cost of material, assembly etc.,
- ratio material costs to power output,
- overall cost saving the GREC can bring compared to existing solutions etc.)
- CO_2 savings
- electricity cost savings
- Estimated costs per kWh in different temperature spans and estimated costs per kWh for different “free existing” temperature spans.
- Carnot efficiency, volume and weight

An overall return on investment study (including investment costs per kWh produced, manufacture and assembly costs…) compared with existing energy production solutions (traditional and renewable)

8) Market analysis

Analysis of the general potential early markets for GREC applications in Sweden:

- what are the needs and the potential future users of the GREC.
- industries which could directly profit from the GREC and be a potential candidate for a prototype 2023
- existing similar competitive solutions?

Expected outcome (deliverables)

The expected outcome of the project is to

Phase 1:
A better understanding of the internal heat exchange mechanism, laminar breakup, WGV-swirl, conducting fin caching, as well as construction and material studies that will result in further mathematical model extensions and simulations regarding the dimensioning of the GREC power output, without emitting any harmful emissions or using rare metals or non-renewable materials.

Phase 2:
The second stage of the project will include further technical research of the full heat exchange mechanism, the energy efficiency. The aim is to find future external heat exchange connections, ”the fuel pipes” which in turn will unlock how to connect or interface existing heat storages for the hot and the cold side of the GREC.

Phase 3
For this third phase of the project, the aim is to develop a scalable design that can be ”calculated” for lots of different applications (size of motor depending on temperature gradient and power output) and deliver detailed specification of a prototype (Lab model v3). The work would enable to advance the Technology Readiness Level (TRL) of the GREC in the direction towards a higher level.

Phase 4
The research enabling a cost comparison study of the GREC solution (both in terms of carbon reduction and economy) versus existing energy production systems, as well as a return of investment and a market analysis study are crucial to showcase the GREC concept and its full potential. This will help to introduce the GREC concept to future industries (industrial partner for a first prototype application of the GREC for spring 2023?).

Future applications

At a glance, key applications of the GREC would include:

- cheap clean high power energy generators (which can deliver continuousoff-grid electricand/or mechanical work),
- industrial waste heat to energy,
- direct solar to motion,
- emission-free technology within the transport sector,
- energy storage applications,
- geothermal motors,
- hybrid hydrogen motors…

Where there are high temperature differences, the GREC can be made small and compact. A suitable engine powering transport in general (car, bus, truck, boat etc.). At lower temperature differences (like waste heat recovery or solar heat), the GREC may be built in very large stationary units with a larger WGV and maximised moving boundary areas, able to deliver great power (e.g. power plants for electricity) but from a low quality heat.
This is a highly scalable, low cost, zero carbon engine that makes the GREC an outstanding competitive solution.

The Technology

In thermodynamic terms the GREC is a closed system with a moving boundary where the GREC converts heat energy to kinetic energy. The GREC heats up and cools down its internal large sliced "Work Generating Volume" (WGV) efficiently, fast and repetitively, resulting in internal pressure changes. These internal pressure changes are used by its moving boundary to generate kinetic energy. You may think of the GREC as a revolving Carnot heat engine controlled by computer logic. Please find the theoretical presentation of the GREC on this link.

We are truly looking forward to advancing the GREC project together with you at Linköping University. Please feel free to call or email:

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