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Some efficient solutions to recover low and medium waste heat: competitiveness of the thermoacoustic technology

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Abstract

Climate change, the policy of the European Union (EU) by 2020 and the carbon-tax make the enhancement of the efficiency of existing processes and the reduction of the fuel consumption an urgent call for the industries. Since most of the wasted energy is discharged in form of hot gases with a low temperature, it makes recovery of this heat a very difficult task, and thus it is important to take a closer look on the existing technologies dedicated to recover low to medium waste heat. This paper details the pros and cons of the Rankine and complexes cycles try to expose a concrete example of each application and finally briefly introduces the potential of the thermoacoustic heat for recovering waste heat and generating electricity.

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Keywords: *Low waste heat; Medium waste heat; efficiency; organic Rankine cycle; thermoacoustic heat engine.*

1. Introduction

Due to climate change and the urgent necessity to strengthen the Europe's competitiveness in the energy field, in 2007, the European Union (EU) has set a Policy known as "20-20-20 targets". The three key objectives for 2020 in

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the EU are:

- 20% reduction in greenhouse gas emissions from 1990 levels.
- 20% energy efficiency increase.
- increase of the part of the renewable energy consumption up to 20% of the energetic mix.

In the French industry, 75% of the final energy is used for thermal purposes such as furnaces, reactors, boilers and dryers. However, around 30% of this heat is assumed to be wasted in the form of discharged hot exhaust gas, cooling water and heated product [1, 2]. In metal and nonmetallic mineral product manufacturing in the United States, 20-50% of the energy is lost as waste heat [2]. In Turkey, in cement plants 51% of the overall heat of the process is unfortunately lost [3]. The combustion of fossil fuels, which generates carbon dioxide emissions, is considered as the primary source of heat production in the industry [1].

For all the above-mentioned reasons, it is necessary to recover waste heat via capturing and reusing for heating or generating electrical or mechanical power in industrial processes. That way, the process efficiency will be increased, less fuel will be consumed and therefore less carbon dioxide will be emitted. Waste heat recovery is a direct solution to achieve the first two key objectives of the EU policy.

However, most of the waste heat which is discharged into the environment during industrial processes is qualified to be low grade heat (temperature lower than 473.15 K) [4, 5] and its recovery depends on the efficiency of the proposed solution: due to its low exergy, low grade waste heat is very difficult to use [6]. Moreover, compared to the quality of the product and the productivity, energy saving is not a major criterion for industry for the moment [1], but with the incentives of the French government to impose the “carbon tax” and with the rising cost of both electricity and fossil fuels resources, the industries will take the waste heat recovery more seriously into consideration.

This document details the available technologies to recover waste heat. It quotes pros and cons of each, limits of application, together with thermal and exergy efficiencies when they are provided in the literature. At the end of this paper, the potential of the thermoacoustic technology to recover heat will be elaborated.

Nomenclature

EU	European Union
ORC	Organic Rankine Cycle
SIC	Specific Investment Cost
KCS	Kalina Cycle System
SRC	Supercritical Rankine Cycle
CO_2	Carbone dioxide
H_2O	Water
THE	Thermoacoustic Heat Engine

2. Classification

If we consider heat from flue gases, vapor streams, cooling water or convective and radiant heat from the hot surfaces of the equipment, the quality of this heat is what matters the most. The temperature at which the heat is discharged can help qualifying the heat. For example: greater potential heat recovery value is assigned to flue gases discharged at higher temperature [7]. It has to be noted that other parameters than the temperature can decrease the quality of the waste heat as the corrosive behavior of some chemicals contained in the discharged fluids. However, waste heat can be classified as [2]:

- High grade heat: temperature is higher than 923.15 K
- Medium grade heat: temperature ranges between 505.15 K and 923.1 K
- Low grade heat: temperature is lower than 505.15 K

According to a study conducted on the industrial energy consumption in 2008 [4], Fig. 1 shows that most of the waste heat is discharged at low temperature (66% below 473.15 K)

Since large quantities of heat are wasted at low to medium temperature, this report focus on the conventional Rankine cycle to recover these types of waste heat. The main aim of this study, is to be able at the end to identify the level of competitiveness of thermoacoustic technology relative for recovering industrial waste heat.

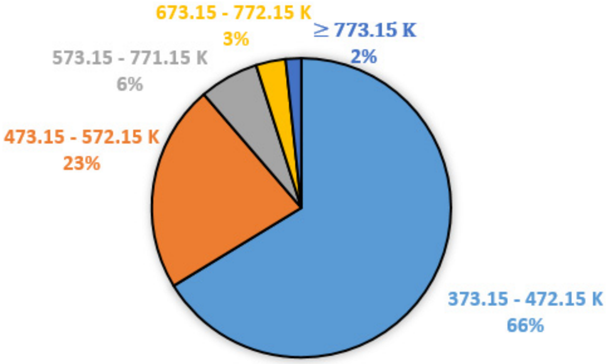

Fig. 1. Waste heat temperature distribution in industry (60TWh) [5]

3. Rankine-Hirn cycle

In a Rankine-Hirn cycle, the heat is extracted from the hot source with a heat exchanger. The working fluid leaving the evaporator drives a turbine to generate mechanical power. The unused residual heat is discharged via the condenser at low pressure. Finally, the fluid is pumped back to the evaporator using a pump. (Fig. 2)

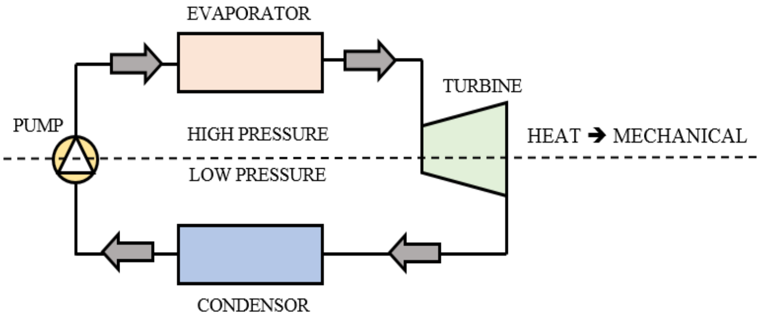

Fig. 2. Main components in a Rankine cycle.
(Evaporation: Process 1-2; Expansion: Process 2-3; Condensation: Process 3-4; Compression: Process 4-1)

3.1. Traditional Rankine-Hirn cycle

Heat sources with temperatures above 613.15 to 643.15 K [8] are used to generate water steam which then drives a steam turbine. To prevent the erosion of the turbine blades, water steam has to be superheated. For low waste heat, traditional Rankine-Hirn cycles become less-cost effective and thus make this cycle out of scope in this paper.

3.2. Organic Rankine Cycle (ORC)

Unlike the conventional Rankine cycle, organic substance replaces the working water and is adapted to low heat source temperature (373.15 K [9]) due to their lower boiling point temperature compared to steam. Some examples of ORC plants are given in this section.

One of the leaders in the development and production of ORC is the European company Turboden (*http://www.turboden.eu*). In recovering waste heat from industrial process, Turboden‘s ORC electric output power ranges from 200 kW to 15 MW[†]. As instance, a remarkable ORC power plant dedicated to recover heat from a cement production industry in Ait Baha (Morocco) delivers 2 MW of electric power. The heat from kiln gas is transferred to thermal oil loop at 573.15 K. The thermal oil feeds the ORC plant which recovers 20% of the heat. This power plant is in operation since 2010. However, this solution is unattractive for applications looking for short payback time (payback of the Turboden’s ORC ranges between 5-10 years based on €0.05-0.08/kWh for electric power rates) [10, 11].

Another example is given by heat waste released from the natural gas pipelines compressors and recovered by a Rankine-based technology manufactured by Ormat. The so-called Ormat energy converter can provide around 5.5 MW of electricity when the exhaust heat from the compressor is around 755.37 K. The thermal efficiency of this power plant is about 12% [12] Based on electric energy cost $0.05/kWh, the payback time is estimated to little-overcome 6 years.

ORCs have been recently identified as a solution for generating electricity from low grade waste heat. Aneke et al. have studied five ORC configurations to recover heat, with temperatures ranging from 393.15 to 485.15 K from a chips manufacturing [14]. The ORC’s working temperatures range from 373.15 to 673.15 K [13]. Performance and economy of an ORC mainly depend on the selection of the working fluid. For example, the increase of the fluid evaporating temperature directly decreases not only the efficiency of the system but also the cost [13]. Quoilin et al. [15] have studied both the economic and the thermodynamic optimization of a small scale ORC dedicated to a heat recovery application. They have shown that the maximum efficiency, which is the ratio of the net electrical output to the actual amount of heat transferred to the evaporator, is around 8%. They have also shown that the optimal specific investment cost (SIC) (ratio of the labor and components cost to the net electric produced power) is 2136 €/kWe (Table 1).

Table 1. Efficiency and specific investment cost of small scale ORC

Fluid	Evaporation temperature (K)	Efficiency of ORC (%)	SIC (€/kWe)
R245fa	409.5	6.964	2700
n-butane	406.35	7.686	2136
HFE-7000	415.55	6.123	3069
n-pentane	413.05	8.369	2505
R123	414.55	8.298	2916
R134a	374.25	5.796	3432
R1234yf	367.57	5.12	4260
SES36	414.75	7.1374	2659

The Clean Cycle ™ 125 produced by General Electric and distributed by Ingeco *(http://www.ingecoweb.com)* can produce around 125 kW electric from a heat source temperature of 423.15 K. The working fluid is the R245fa.

The heat temperature input is flexible and can decrease until 394.15 K

3.3. Kalina Cycle System (KCS)

The Kalina cycle is an evolution of the Rankine cycle using an ammonia/water mixture as the working fluid. The mixture does not fully evaporate in the evaporator; a separator is thus required to unload the unevaporated fraction going through the turbine. The Kalina cycle is another choice to recover heat from low grade geothermal source heat [17]. The thermal efficiency of the Kalina cycle depends strongly on the ammonia mass fraction in the mixture and the inlet pressure at the turbine. For a higher turbine inlet pressure, an ammonia-richer mixture is suited to recover the maximum of heat and thus the cycle thermal efficiency is increased. However, handling a high pressure in the cycle seems to be an unpractical task [19].

Two main Kalina cycle systems were identified to recover heat from low grade heat source [16].

- The KCS 11 (Fig. 3) for heat source temperatures ranging from 394.15 to 477.15 K: an absorber type element is introduced in the basic cycle, varying the concentration of the ammonia at different working points of the mixture.
- The KCS 34 (Fig. 4) for heat source temperatures below 394.15 K.

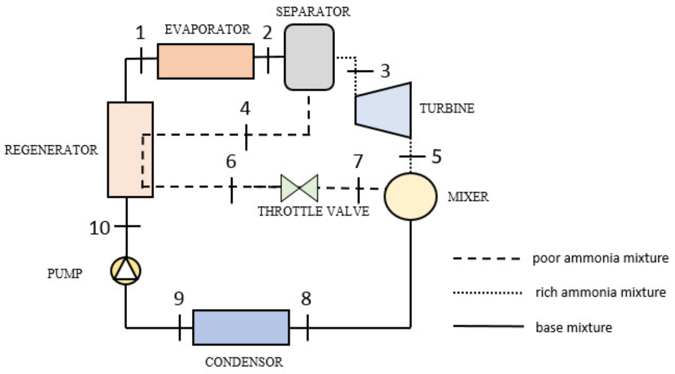

Fig. 3. Schematic diagram of the KCS 11 [16]

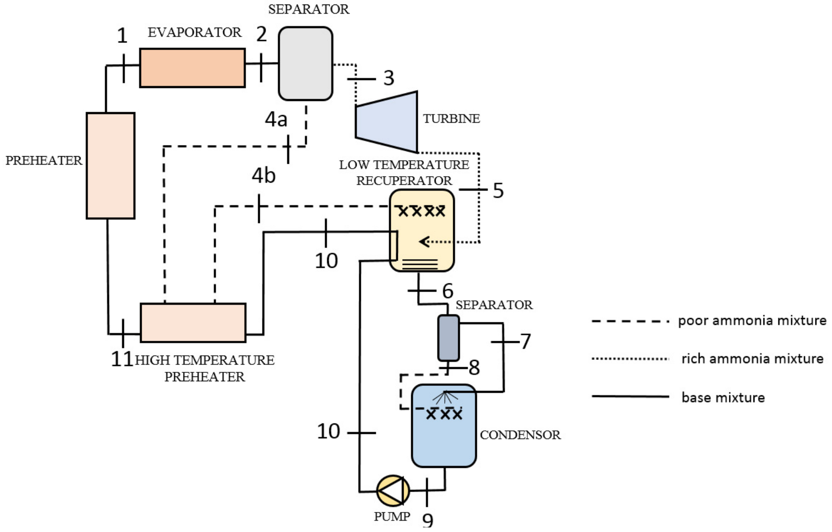

Fig. 4. Schematic diagram of the KCS 34 [18][19]

Global Geothermal Limited is the proprietary of the Kalina Cycle ® which has been selected as a suitable solution to recover heat in a diverse range of projects detailed in Table 2.

Table 2. Current applications of the Kalina cycle [20].

Name	Commissioned in	Located in	Resources	Power output	Heat source
Kashima	September 1999	Japan	Industrial process heat (Cooling water)	3450 kW	371.15 K
Húsavik	July 2000	Iceland	Geothermal	1700 kW	394.15 K
Fuji oil	September 2005	Japan	Hydrocarbon processing (Eureka process)	3900 kW	391.15 K
Unterhaching	April 2009	Germany	Geothermal	3400 kW	395.5 K
Bruchsal	December 2009	Germany	Geothermal	580 kW	391.15 K
Expo 2010	May 2010	China	Solar thermal resources	50 kW	365.15 K

Jiacheng et al. [16] have studied the performance of two modified KCS 11 based systems. It has been shown that the thermal efficiency from a heat source of 400.14 K is around 12% and that the exergetic efficiency ranges from 50 to 65%. Mlcak et al. have shown that a KCS 34 Kalina cycle has a higher performance (20 to 25%) compared to an ORC performance [21]. The crucial claims of the efficiency advantages of the Kalina cycles over the ORC have motivated DiPippo to conduct a comparative study based on the second law of thermodynamics [18]. The performance of two plants already in operation (Brady and Húsavik) is simulated under common input, environmental conditions and cooling system. Results show that the Kalina cycle might improve the performance of only 3% compared to an ORC [18].

It has to be noted that in geothermal field, ORC is a mature technology Table 3 details the characteristics of some ORC binary geothermal power plant in operations. Table 2 details the different applications of the Kalina cycles in operation. Moreover, compared to conventional ORC, Kalina cycles are more complex and require higher maintenance and capital outlay [9].

Table 3. Characteristics of geothermal power plants in operations [28].

Name	Otake	Nigorikawa	Heber SIGC
Location	Kyushu (Japan)	Hokkaido (Japan)	Imperial Valley (CA USA)
Type	ORC	ORC	ORC
year	1980	1980	1993
Brine inlet temperature	403.15 K	413.15 K	438.15 K
Dead state temperature	291.15 K	286.15 K	288.15 K
Working fluid	isobutane	R114	Mixture of isobutane & isopentane
Plant rated power	1000 KW	1000 KW	6875 KW
Thermal efficiency	12.9%	9.8%	13.2%
Exergetic efficiency	53.9%	21.6%	43.4%
Remarks	18-stage flash evaporator	2 stage condenser	Six integrated dual level units
Figure	Fig. 5 (a)	Fig. 5 (b)	Fig. 5 (c)

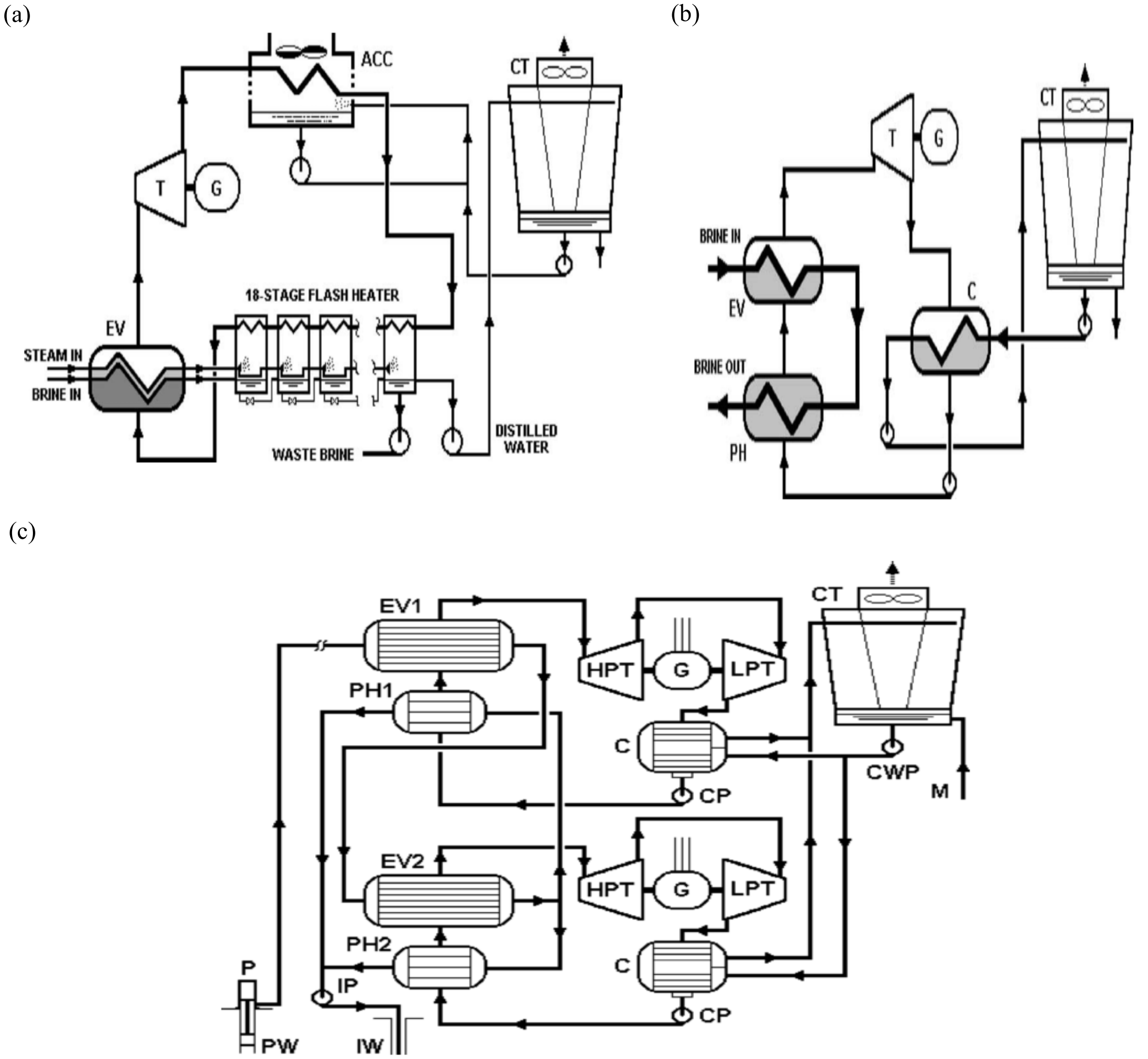

Fig. 5. (a) Schematic of the Otake binary plant (b) Schematic of the Nigorikawa binary plant (c) Schematic of the Heber binary plant [28] (ACC: Air Cooled Condenser; C: Condenser; CP: Condensate Pump; CT: Cooling Tower; CWP: Cooling Water Pump; EV: Evaporator; HPT: High Pressure Turbine; IP: Injection Pump; LPT: Low Pressure Turbine; P: Pump; PH: Preheater; PW: Production Well; T: Turbine)

3.4. Supercritical Rankine Cycle (SRC)

Once heated, the working fluid (Carbon dioxide (CO_2), Water (H_2O) or hydrocarbons) of a SRC bypasses the two phase region directly from the liquid state to the supercritical state. Hence, the thermal efficiency of the process is enhanced and the exergy destruction is lowered since the mismatch between the temperature profiles between the working fluid and the source, or simply the pinch, is reduced in the heat (Fig. 6)

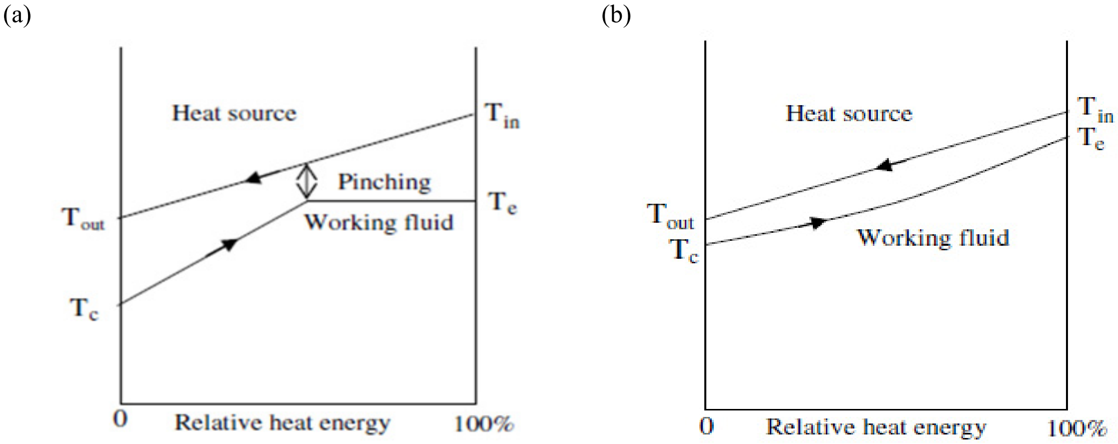

Fig. 6. Heat transfer between waste heat and the working fluid in the main heat exchanger. (a) Case of an ORC (b) Case of a SRC [22]. (T_{in}: Inlet temperature of the heat source; T_{out}: Outlet temperature of the heat source; T_c: Inlet temperature of the working fluid; T_e: Outlet temperature of the working fluid)

According to Y. Chen et al., the CO_2-SRC power cycle output is slightly higher than the R123-ORC cycle, when recovering heat from a low grade source [22]. Since the higher output power is not reached when the efficiency of the process is at its maximum, and especially with the lack of researches on the CO_2 power cycles, it is very difficult to judge whether the SRC is better suited to recover wasted heat than the ORC. However, the CO_2 presents some advantages that are worth to be mentioned and makes of the CO_2–SRC a serious competitor to the ORC:

- Moderate value of the critical pressure (73.8 bars)
- Well-known thermodynamics properties
- Abundant in the nature and thus inexpensive
- Non-explosive and non-corrosive
- High density which means a compact turbomachinery

The SRC-CO2 heat engine build by Echogen can deliver from 250 kWe to 50 MWe with efficiency up to 30%. The very compactness of this technology makes it a very attractive solution to recover heat especially when the space is not freely available.

4. Thermoacoustic heat engine (THE)

A break-up in the conversion processes is the thermoacoustic technology where the thermal to acoustic power switch is occurring. In general, the thermoacoustic is the coupling phenomenon of the sound wave propagation described by the motion, pressure and temperature oscillations and the oscillating heat transfer between the compressible fluid (gas in the most of cases) travelling within a small channel and the neighboring solid boundaries. In a thermoacoustic engine, the conversion of thermal to acoustic energy takes place in a porous media called regenerator or stack. This device is sandwiched between two heat exchangers (HEXs) to form the heart of the engine called the wave generator (Fig. 7). Connected to thermal reservoirs, the cold HEX connected to the sink at T_c and the hot HEX connecting to the source at T_h are able to maintain a temperature gradient (ΔT), along the regenerator or stack. Due to this temperature gradient a sound wave is induced and is able to be amplified by extracting the heat (Q_h) from the hot source and evacuate the unconverted residual heat (Q_c) to the cold sink. Actually the oscillation in motion of the wave displaces the parcel of the working fluid in a way that the parcel of gas experiences compression and expansion depending on the oscillation in pressure (Fig. 8) while it is exchanging heat with the solid boundaries in the porous media. As such, the gas parcel will undertake a thermodynamic cycle and acoustic power is pumped by the wave generator.

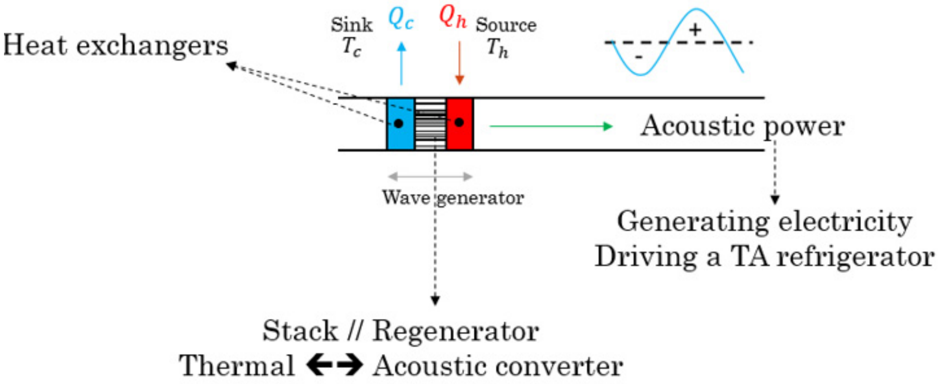

Fig. 7. Scheme of the wave generator in a THE.

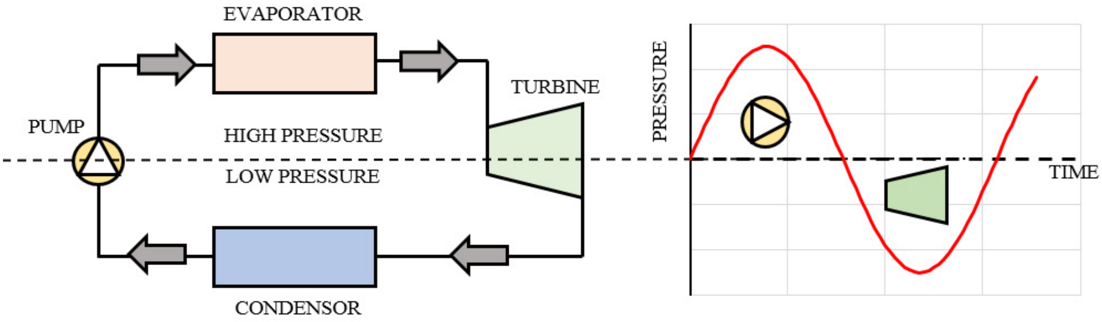

Fig. 8. Analogy between the pressure oscillations and the roles of the turbine and the pump in a Rankine cycle.

THE is a promising new technology that is able to capture waste heat and produce acoustic energy. The acoustic energy is then used to drive a thermoacoustic cooler or simply moves a solid piston sealed to a moving rod in a magnetic field in a linear alternator to generate electricity. Depending on the nature of the wave, whether it is a travelling or a standing wave, two types of devices can be identified. It has to be noted that this approach of classification is theoretical. Practically no apparatus works with a pure standing nor a pure travelling wave.

In a standing wave heat engine, the oscillation pressure is about 90° out of phase with the oscillating velocity (Fig. 9 (a)). In the stack (Fig. 9 (b)) the gas parcel experiences compression or expansion while it is displaced within a peak-to-peak distance (2ξ). Heat transfer occurs when the gas parcel is only tracing the limit of the boundary layer: the distance from the solid surface (y) is approximately equal to the thermal boundary layer (δ_κ) (Fig. 9 (c)).

In a travelling wave heat engine, the oscillating pressure is in phase with the oscillating velocity (Fig. 10 (a)). In the regenerator (Fig. 10 (b)) an enhanced thermal contact between the gas parcel and the solid surfaces is ensured by the small hydraulic ratios: y<< δ_κ; inevitable viscous losses in the solid matrix of the regenerator make the theoretical perfect thermal heat exchange impossible. The gas parcel travels along the channel within a peak-to-peak distance (2ξ) inside the thermal penetration depth (Fig. 10 (c)), exchanging heat isothermally in each location of the regenerator.

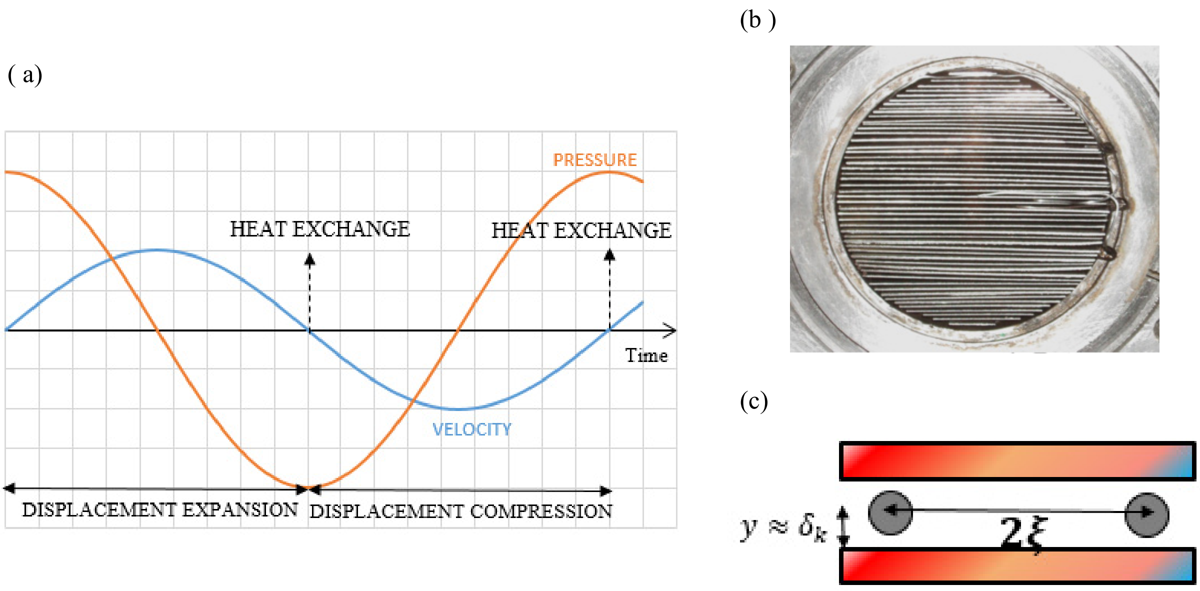

Fig. 9. (a) Pressure and motion variation in a standing wave engine. (b) Top view of the stack. (c) Parcel of gas tracing the limit of the thermal boundary layer in the stack.

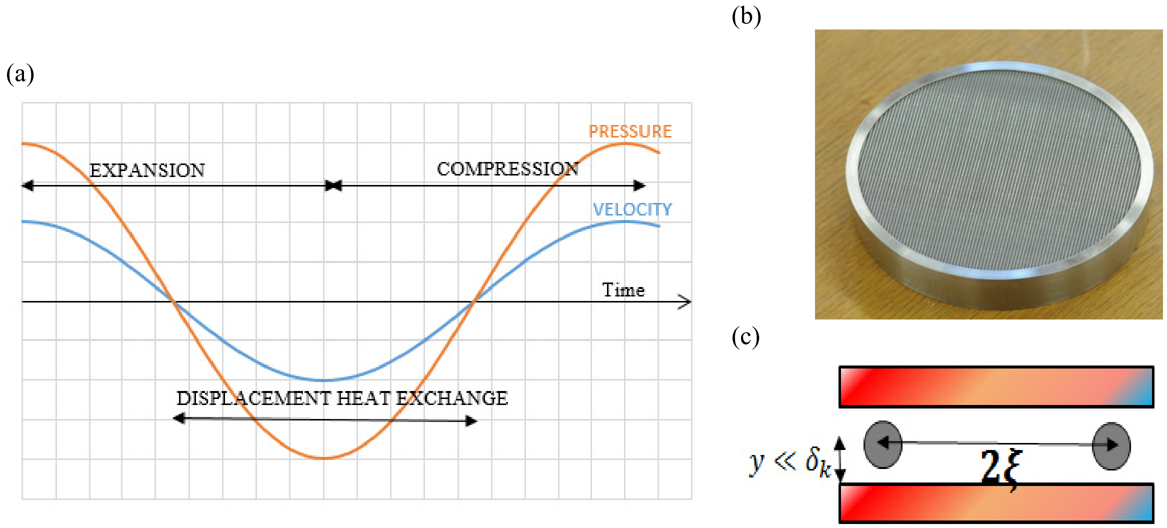

Fig. 10. (a) Pressure and velocity variation in a travelling wave engine. (b) Regenerator. (c) Parcel of gas within the thermal boundary layer in the regenerator.

Currently, efforts are dedicated to enhance the potential of the thermoacoustic in studying a thermal source technology which does not depend on the nature of the source, in recovering waste heat or using solar energy.

This simple, reliable and low-cost engine requires no moving parts, no exotic materials, no close tolerances and an environmentally friendly working fluid (helium, air, argon). Moreover, unlike the previous technologies (ORC and KCS), this heat engine is relatively compact with a probable thermal efficiency up to 30% [24, 25]. A study [26] on a portable standing wave thermoacoustic engine driven by atmospheric air is dedicated to serve rural communities by recovering the wasted heat issued from a cook stove. The experimental investigations have shown that this compact apparatus can deliver 50 W of electricity from a heat source at 723.15 K. Tijani et al. (Fig. 11) have proven that a thermoacoustic heat engine produced 3kW of acoustic power with achievable 41% of the Carnot performance, heat source being at 893.15 K.

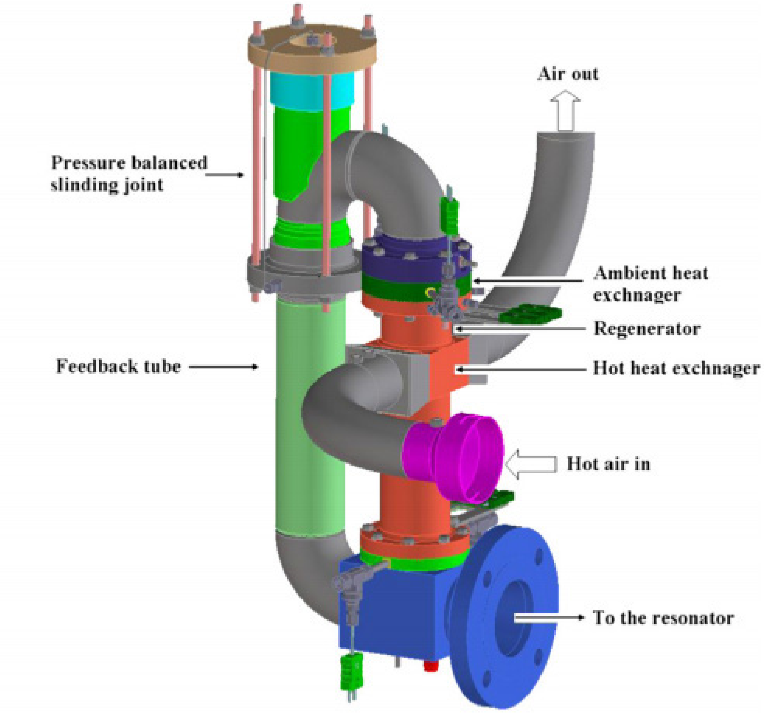

Fig. 11. CAD drawing of the thermoacoustic engine studied by Tijani et al. [27]

Despite all the advantages of the thermoacoustic engine, it could be noted that the thermal power input is limited by a maximum length of the HEXs in the direction of the wave propagation according to the acoustic displacement and thus leading to a limited heat exchange surface. Moreover, HEXs must have a uniform temperature distribution; otherwise streaming phenomena can appear and degrade the performance of the thermo-acoustic conversion. To overcome this inconvenience and as an example of a promising application, HEKYOM with the collaboration of EReIE and ASTER THERMOACOUSTICS is developing a thermoacoustic engine with three thermoacoustic amplification cells (Fig. 12) to increase by 10% the efficiency of an internal combustion engine. The heat transfer between the source and the working fluid (helium) is insured by a loop heat pipe. Moreover, the recuperators allowing heat recovery from the exhaust gases of the internal combustion engine are easy removable when they are subject to fouling. Once amplified, the acoustic energy is converted into electricity. Using this process, the available waste heat is limited to 90% by the dew-point of the gases. In the HEKYOM prototype, the overall thermal energy is around 70 kW and the efficiency of thermal to acoustic conversion is high enough to compete with Rankine cycles.

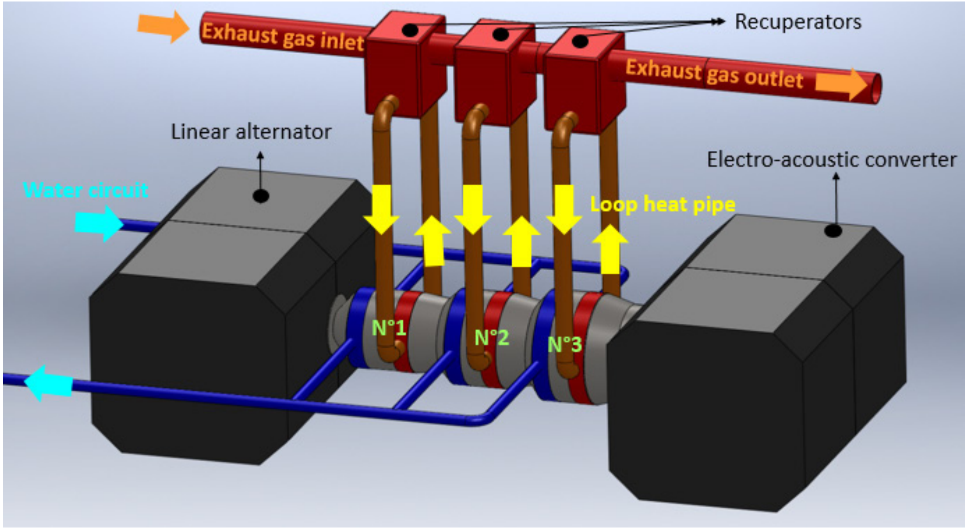

Fig. 12. THE developed by HEKYOM.

5. Conclusion and perspectives

In this study, the potential of existing solution to recover medium and low waste heat is investigated. The organic Rankine cycles are the most famous in this field, however their efficiency depend on the selection of the working fluid, which can change from an application to another. The Kalina cycles are more complex and cannot be compared easily to the organic Rankine cycle ORC. The superheated Rankine cycle SRC might have a great future potential, however yet there is a lack in the conducted studies on the CO_2 cycles. Thermoacoustic is a new promising technology. Its advantages could enable this technology to compete with the conventional Rankine-Hirn cycles. However, additional efforts must be dedicated to design, build and test within an experimental investigation of the performance of this engine. Energetic and exergetic optimization coupling the acoustic field to the heat exchanger is necessary to make from the thermoacoustic an outstanding technology in terms of performance, cost and reliability.

References

[1] Dupont M, Sapora E. The heat recovery potential in the French industry: which opportunities for heat pump systems? ECEEE 2009 Summer Study, 1-6 June 2009, La Colle sur Loup (France), pp. 1115-1123.
[2] BCS, Incorporated (March 2008), Waste heat recovery: technology and opportunities in U.S. Industry. [Online] Available: https://www1.eere.energy.gov/manufacturing/intensiveprocesses/pdfs/waste_heat_recovery.pdf
[3] Söğüt Z, Oktay Z, Karakoç H. Mathematical modeling of heat recovery from a rotary kiln. Applied thermal engineering 2010 (30 (8-9)); pp. 817-825
[4] Fang H, Xia J, Zhu K, Su Y, Jiang Y. Industrial waste heat utilization for low temperature district heating, Energy policy 2013 (62); pp. 236-246.
[5] CEREN, Le potentiel de récupération de chaleur fatale à 100°C et plus dans l'industrie (private communication, November 2012).
[6] Kaşka Ö. Energy and exergy analysis of an organic Rankine for power generation from waste heat recovery in steel industry. Energy Conversion and Management 2014 (77); pp. 108-117.
[7] Reay DA. Heat recovery systems: a directory of equipment and techniques. 1st ed. London: E. & F.N. Spon; 1979
[8] Penn State University, U.S. Department of Energy, Mid-Atlantic Clean Energy Application Center. Waste heat to power technology. [Online] Available: http://www.maceac.psu.edu/cleanenergy_whr_heat-to-power.html [2014, March 18]
[9] Law R, Harvey A, Reay D. Opportunities for low-grade recovery in the UK food processing industry. Applied thermal engineering 2013 (53 (2)); pp. 188-196.
[10] Vescovo R (August 2011). Waste heat into power. In the International Cement Review. [Online]

Available: http://www.turboden.eu/en/public/press/20111025162659328.pdf [viewed 2014, March 18]

[11] Vescovo R (June 2012). Making more of waste heat. In the International Cement Review. [Online]
Available: http://www.turboden.eu/en/public/press/120604_ARTICOLO%20VESCOVO_CEMENT%20REVIEW.pdf viewed 2014, March 18]

[12] Nazir P, Jones S, Schochet D, Posner D (2004). Utilization of Turbine waste heat to generate electric power at Neptune plant. [Online]
Available: http://www.ormat.com/research/papers/utilization-turbine-waste-heat-generate-electric-powerat-neptune-plant.html viewed 2014, March 18

[13] Chan CW, Ling-Chin J, Roskilly AP. A review of chemical heat pumps, thermodynamic cycles and thermal energy storage technologies for low grade heat utilization. Applied thermal engineering 2013 (50 (1)); pp.1257-1273.

[14] Aneke M, Agnew B, Underwood C, Wu H, Masheiti S. Power generation from waste heat in a food processing application. Applied thermal engineering 2012 (36); pp. 171-180.

[15] Quoilin S, Declaye S, Tchanche BF, Lemort V. Thermo-economic optimization of waste heat recovery Organic Rankine Cycles. Applied thermal engineering 2011 (31 (14-15)); pp. 2885-2893.

[16] He J, Liu C, Xu X, Li Y, Wu S, Xu J. Performance research on modified KCS (Kalina Cycle System) 11 without throttle valve. Energy 2014 (64); pp. 389-397.

[17] Arslan O. Exergoeconomic evaluation of electricity generation by the medium temperature geothermal resources, using a Kalina cycle: Simav case study. International journal of thermal sciences 2010 (49 (9)); pp.1866-1873.

[18] Arslan O. Power generation from medium temperature geothermal resources: ANN-based optimization of Kalina cycle system-34. Energy 2011 (36 (5)); pp. 2528-2534.

[19] Singh OK, Kaushik SC. Energy and exergy analysis and optimization of Kalina cycle coupled with a coal fired steam power plant. Applied thermal engineering 2013 (51 (1-2)); pp. 787-800.

[20] Global Geothermal Limited (August 2010). Iron & Steel industry. [Online]
Available: http://www.proactiveinvestors.com/genera/files/sponsor_files/ironsteel.pdf viewed 2014, Mars 18

[21] Mlcak H, Mirolli M, Hjartason H, Húsavíkur O, Ralph M (2002). Notes from the North: a report on the debut year of the 2MW Kalina Cycle Geothermal power plant in Húsavik, Iceland. [Online]
Available: http://www.kecpower.com/public/wp-content/uploads/2002/08/HusavikGRC2002.pdf [viewed 2014, Mars 18]

[22] Chen Y, Lundqvist P, Johansson A, Platell P. A comparative study of the carbon dioxide transcritical power cycle compared with an organic Rankine cycle with R123 as working fluid in waste heat recover. Applied thermal engineering 2006 (26 (17-18)); pp. 2142-2147.

[23] Persichilli M, Kacludis A, Zdankiewics E, Held T. Supercritical CO_2 power cycle developments and commercialization: Why sCO_2 can displace steam. Power-Gen India & Central Asia 2012, 19-21 April 2012, New Delhi (India).

[24] Mumith J-A, Makatsoris C, Karayiannis TG. Design of a thermoacoustic heat engine for low temperature waste heat recovery in food manufacturing: A thermoacoustic device for heat recovery. Applied Thermal Engineering 2014 (65(1-2)); 588-596

[25] Yu G, Wang X, Dai W, Luo E. Study on energy conversion characteristics of a high frequency standing-wave thermoacoustic heat engine. Applied energy 2013 (111); pp. 1147-1151.

[26] Normah MG, Irfan AR, Koh KS, Manet A, Zaki Ab M. Investigation of a portable standing wave thermoacoustic heat engine. Procedia Engineering 2013 (56); pp. 829-834.

[27] Tijani TM, Spoelstra S. A hot air driven thermoacoustic Stirling engine. Applied Thermal Engineering 2013 (61 (2)); pp. 866-870.

[28] DiPippo R. Second law assessment of binary plants generating power from low-temperature geothermal fluids. Geothermics 2004 (33 (5)); pp. 565-586.