



INDUSTRY
Greenline



New applications – Process integration

ORC for jet cooling sections of galvanizing and annealing steel processing lines

E. Pinto de Sousa , L. Ferrand, Samer Maaraoui, Elias Boulawz Ksayer, Denis Clodic, Xueqin Pan

October 7th & 8th 2013 De Doelen, Rotterdam, The Netherlands

Agenda



ORC for jet cooling sections

1 Industrial context of steel processing lines

2 Process integration

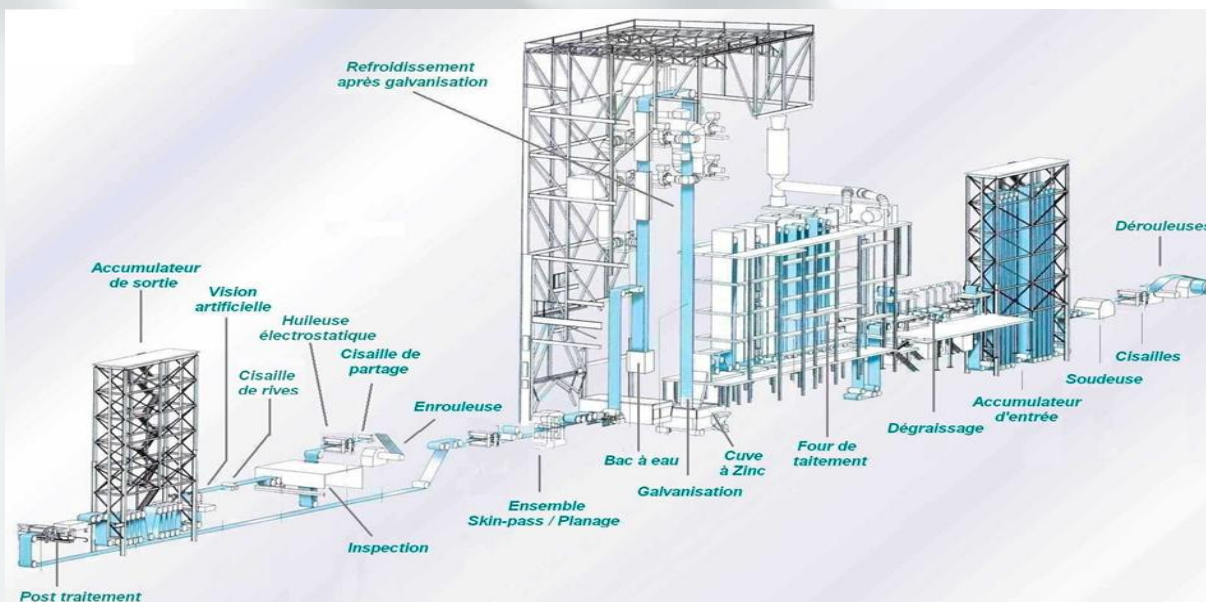
3 Case study and market potential

Industrial context of steel processing lines

The galvanizing process is used to coat steel (carbon, stainless, silicon) to prevent steel from oxidation

Galvanized steel is used for many applications : automotive industry, buildings, roofs and walls or even electrical applications

Steel is coated in a zinc bath on vertical or horizontal galvanizing lines



Industrial context of steel processing lines

The jet cooling process is one of the most important of the galvanizing process due to the manufacturer's demand for specific steel metallurgic properties that must be accomplished with the adequate cooling rates.

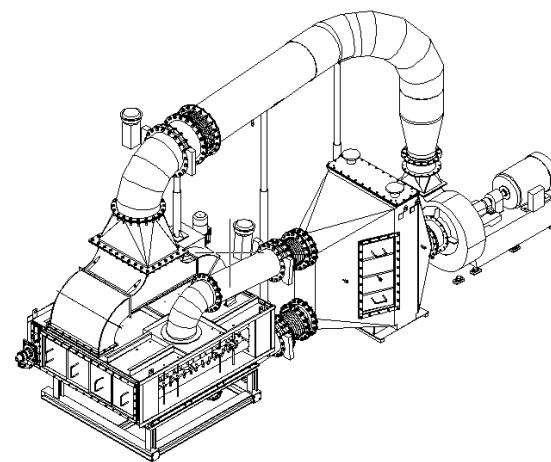
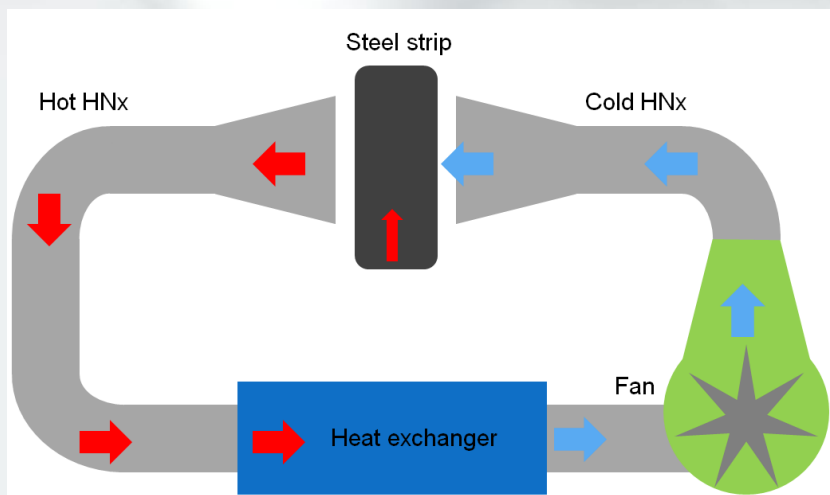
Cooling the steel strip is done by impinging nozzles or slots of an hydrogen-nitrogen content gaz (HNx)

This gas blown at the strip at a maximum speed of 120 m/s extracts the steel strip available heat by forced convection.



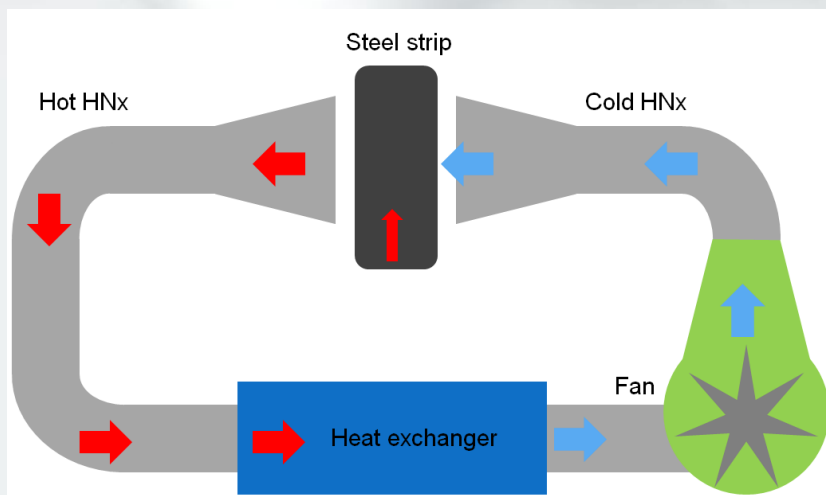
Industrial context of steel processing lines

- The strip is cooled down to the zinc pot temperature $\sim 460^{\circ}\text{C}$
- A fin-tube heat exchanger running with cold water coming from the aero-refrigerants runs on a closed loop circuit
- A fan blows cold HNx ($50\text{-}100^{\circ}\text{C}$) and hot HNx is recirculated ($150\text{-}250^{\circ}\text{C}$)
- Due to the HNx mass flow the fan electrical consumption is not negligible



Industrial context of steel processing lines

- The strip is cooled down to the zinc pot temperature $\sim 460^{\circ}\text{C}$
- A fin-tube heat exchanger running with cold water coming from the aero-refrigerants runs on a closed loop circuit
- A fan blows cold HN_x ($50\text{-}100^{\circ}\text{C}$) and hot HN_x is recirculated ($150\text{-}250^{\circ}\text{C}$)
- Due to the HN_x mass flow the fan electrical consumption is not negligible



All the energy extracted from the steel strip is invariably lost !



ORC for jet cooling sections

1 Industrial context of steel processing lines

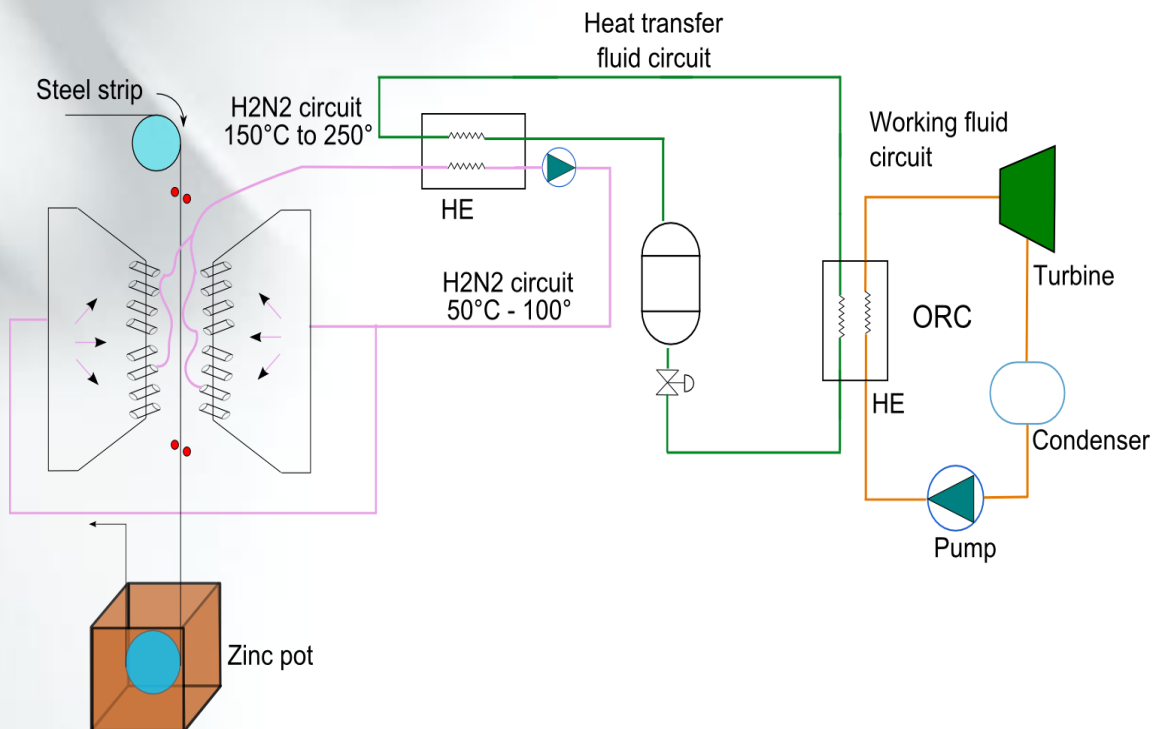
2 Process integration

3 Case study and market potential

Process integration

At the beginning of the project, a lot of technical choices had to be addressed :

- The heat exchanger whose design must be changed for maximum output
- Heat transfer fluid
- Working fluid
- Variability of the heat source
- Type of expansion



Project ORC-2-MECA

Project ORC-2-MECA

Goal

Partners



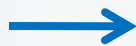
ORC coupling with strip cooling system

- Subsidized by ADEME (French Environment and Energy Management agency)
- 18 month Research Project
- Targeting CGL and CAL processing lines



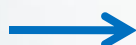
• Divided into 3 steps :

Step 1



Recuperative system conception

Step 2



ORC conception

Step 3



Technical and economical optimization

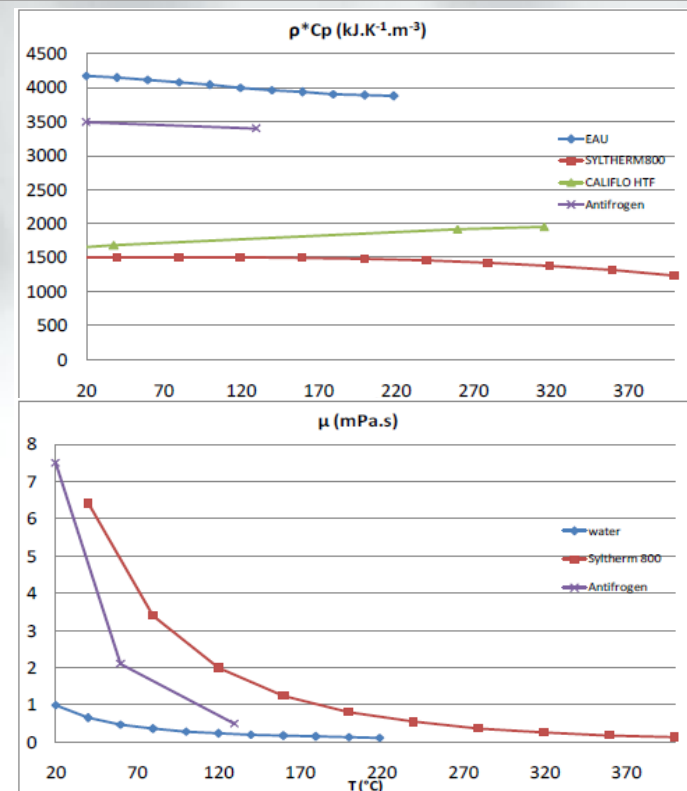
Heat transfer fluid and working fluid

Concerning the heat transfer fluid, a comparison was made between water, syltherm, calflo and antrifrogen

Water presents itself as the most suitable heat transfer fluid due to its high thermodynamic properties and availability.

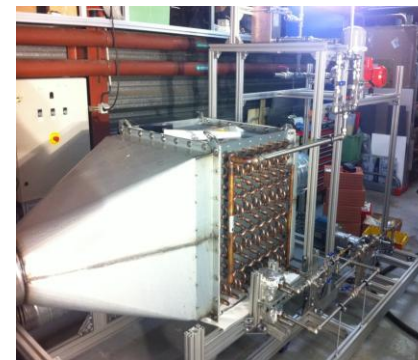
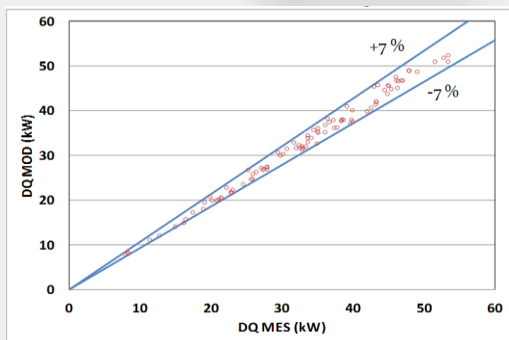
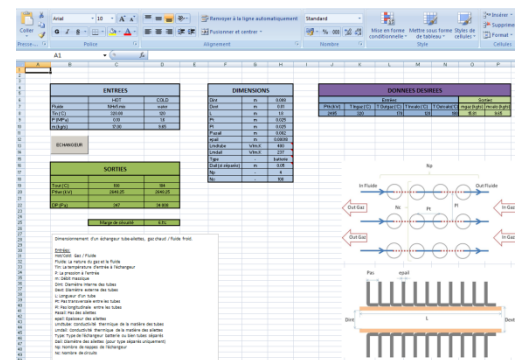
➤ Steel manufacturers are well acquainted with this fluid unlike thermal oils for example

➤ Concerning the working fluid, special attention has been given to R245fa and R1234ze. R245fa outperforms R1234ze in terms of efficiency and has the advantage of being a non-flammable fluid though its GWP is not negligible and it has a higher expansion rate compared to R1234ze.



HNx heat exchanger(s)

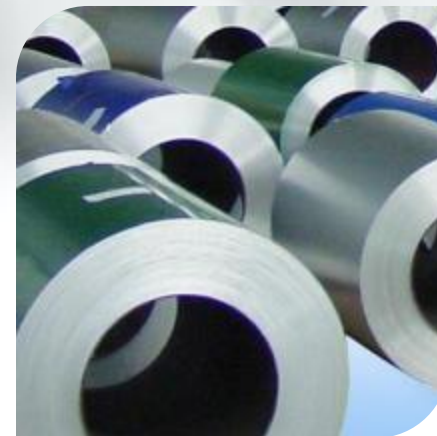
- Optimisation of the heat exchangers HNx – heat transfer fluid
 - Technical choices of suppliers, fin an tube materials, suitable arrangement of fin and tubes
 - Development of an heat exchanger dimensioning tool
 - Heat exchanger test rig and model validation
- An optimised heat exchanger will have 3 to 8 times more volume than the current heat exchangers.



Variability of the heat source

Steel manufacturers deal with a large variety of coils with different thickness [0.3 – 2.5 mm] and width [800 – 1900 mm].

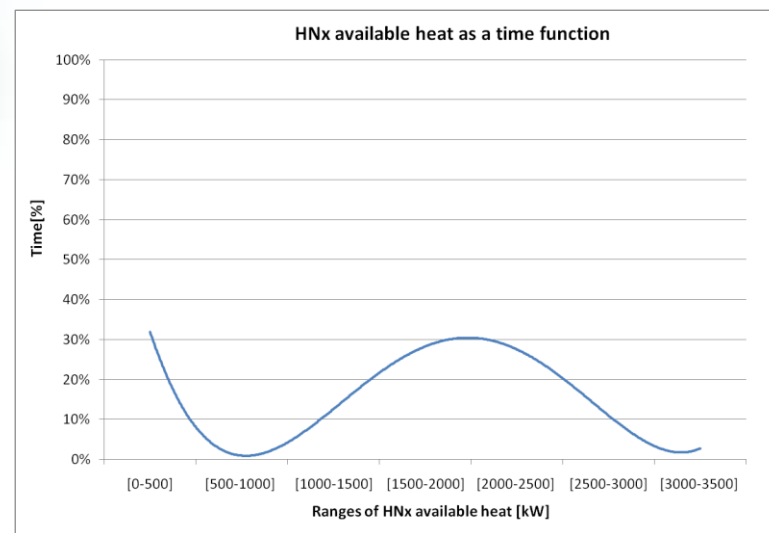
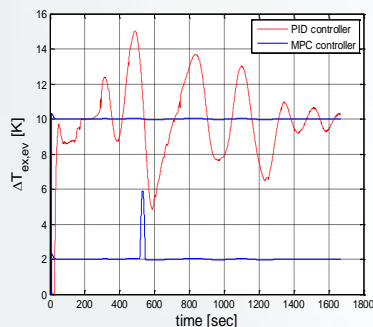
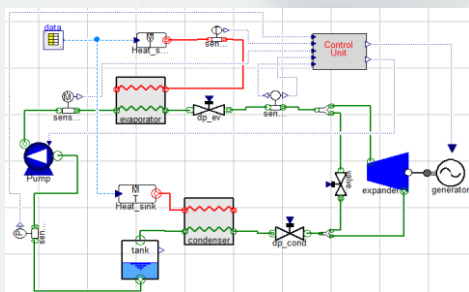
In addition, several metallurgical thermal cycles are available in order to have different types of steel properties.



➤ The heat source available is not constant and suffers considerable variations



Need for control systems bringing more stability and anticipation than the classic methods



Type of expansion

When dealing with low grade sources, an extremely important issue is the total installed cost of the turbine which is , by far, the most expensive one.

This fact makes ORC non profitable for waste heat recovery most of the times.

➤ A low-cost expander can be obtained by retrofitting existing compressors. Due to the high production volume of these machines, prices may become competitive

Some advantages : price-competitive, easy to install, tight design, Inductor/generator included and can be installed in series to deliver the power demanded



ORC for jet cooling sections

1 Industrial context of steel processing lines

2 Process integration

3 Case study and market potential

Case study / market potential

Taking as an example the following characteristics :

Strip cooling from 600°C to 380°C
 Line speed = 450 m/min
 Strip width = 1300 mm
 Strip thickness = 0.25 mm

Case Study

HNx temperature	135	°C
HNx available heat	3170	kW
Total delays	25	%
3 weeks for annual stoppage	504	hours
Net production time / year	6100	hours
Heat - electric conversion	12	%
Yearly electric output	2.3	GWh

Market Potential

		France	Europe	World
Number of galvanizing and annealing lines	-	11	105	300
Yearly electric output	GWh	26	244	696
Tons of CO2 avoided (396 g/kWh UE27)	tons	10 108	96 484	275 668

Conclusions

- It has just been presented an innovative application to produce electricity from jet cooling gases of galvanizing and annealing processing lines that can be deployed on new lines as well as existing ones
- This application allows steel manufacturers to produce electric power to compensate current fans electric consumption without impacting the process and strip quality
- A pronounced variability of the heat source is present due to different thermal cycles and coils. Therefore, there is the need for robust control systems with predictive capabilities
- New technologies are emerging when it comes to fluid expansion. Finding a compromise between isentropic efficiency and cost can play an important role to ORC market penetration

Thank you for your kind attention