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

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Agenda

1. Industrial context of steel processing lines
2. Process integration
3. Case study and market potential
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.
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.
The strip is cooled down to the zinc pot temperature ~ 460°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 (50-100°C) and hot HNx is recirculated (150-250°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 ~ 460°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 (50-100°C) and hot HNx is recirculated (150-250°C)
- Due to the HNx mass flow the fan electrical consumption is not negligible

All the energy extracted from the steel strip is invariably lost!
1. Industrial context of steel processing lines
2. Process integration
3. Case study and market potential
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

- 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
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.
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.

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.
3. Case study and market potential

2. Process integration

1. Industrial context of steel processing lines

ORC for jet cooling sections
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

### Market Potential

<table>
<thead>
<tr>
<th></th>
<th>France</th>
<th>Europe</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of galvanizing and annealing lines</td>
<td>-</td>
<td>11</td>
<td>105</td>
</tr>
<tr>
<td>Yearly electric output</td>
<td>GWh</td>
<td>26</td>
<td>244</td>
</tr>
<tr>
<td>Tons of CO2 avoided (396 g/kWh UE27)</td>
<td>tons</td>
<td>10 108</td>
<td>96 484</td>
</tr>
</tbody>
</table>

### 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

### CO2 Avoided

- **Tons of CO2 avoided (396 g/kWh UE27)**:
  - France: 10 108 tons
  - Europe: 96 484 tons
  - World: 275 668 tons

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**France**

**Europe**

**World**

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Conclusions

• It has just been presented an innovative application to produce electricity from jet cooling gases of galvanizing and annealing processing lines that can 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