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ANALYSING THE ENERGETIC POTENTIAL OF THE COOLING WATER WITHIN THE CONTINUOUS CASTING PROCESS OF STEEL

Gabriela Liliana DEAC, Cristina Daniela HORJU-DEAC, Ioan BIRIŞ, Tiberiu RUSU

Abstract: *The present paper aims at the evaluation of the energetic potential of cooling water on the continuous steel casting technological line. The energy fluxes afferent to balance contour are determined on the bases of measurements carried on by the authors. The energy dissipated is intuitive presented by Sankey graphical diagrams, putting in the evidence the share of the heat lost through the cooling water. The paper provides useful information for devising measures for recuperation and turning to good account of available secondary resources.*
Key words: *cooling water, continuous casting, energetic balance, secondary energetic resource, hermalpotential*

1. INTRODUCTION

The issue of resources has become generalized problem of the whole world and not only of single country. The European Union has adopted the most important set of anti-change climatic politics, the Climates Plan “20-20-20” , in whose framework, one of its sustainable development targets, refer to diminishing the primary energy consumption by 20% until 2020 [8]. The usual synthetic expression in Romania, which characterized the primary energy resources, is that “we are a rich country in poor energetic resources” [1].

A sustainable alternative for the natural resources consists in turning to good account of the secondary resources of energy (RSE). The advantageous used of these resources by measures of increasing energetic efficiency requires a better understanding of their energetic potential [7].

2. CHARACTERISTICS OF COOLING WATER

Water as a cooling agent has the capacity of transmitting energy through a distance efficiently. The high specific heat and high thermal conductivity make it a very good heat transporter and most widely used thermal cooling agent in industry, taking over the heat emerging from technological processes and industrial equipment [4].

The cooling water represents the most important category of industrial residual water, as quality is concerned. It results that the major consumer of such water is the metallurgical industry with an average consumption of 80% of the total volume [9].

The figure 1 presents a diagram of the comparative quantities of residual water used in industry.

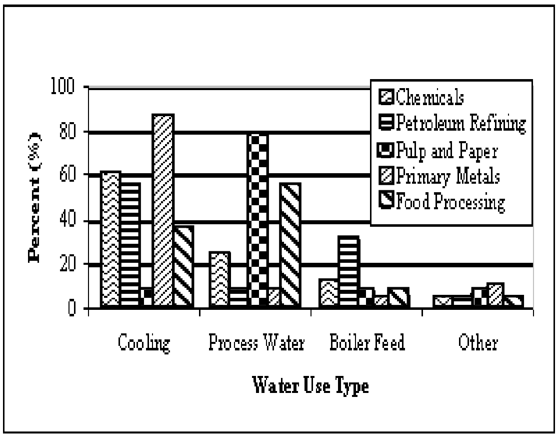

Fig. 1. *Water use type in industry. [9]*

The qualitative requirements for industrial water are more diverse than with drinking water even though this has less quality indicators.

The main requirements are as follows [2]:

- it should not corrode pipes, fittings and equipment;
- it should not deposit salts, solids and nind;
- it should contain least salts, especially calcium and magnesium;
- it should not have acid reactions;
- it should not provide favourable conditions for developing biomass along technological circuits.

The industrial water should have temporary hardness of 1-2^{0}h and oveall hardness of maximum 15^{0} h, [6]. The thermal potential of input water to cooling plant should lie between T = 19 ÷ 22 ^{0}C.

In table 1, the values of some quality indicators are presented, the suspensions, the salinity and CBO_5.

Table 1.

Quality indicators of industrial water, [6].

Purpose		Suspensions [mg/l]	Salinity [mg/l]	CBO_5 [mg/l]
no-contact of cooling	with the product	10	500	5
	with the raw material	20 – 100	500 - 1500	5 –10
contact cooling	with the product	20 – 100	500 –1500	5 –10
	with the raw material	10	500	5

The water used in the cooling process needs a preliminary treatment of softening a fact that induces further expenditure.

The industrial water meant for cooling processes after passing along the useful course, is still relatively clean, as it is but thermally polluted (affected). In its analysis the following aspects should be synthesized: the generation of the pollutant, its impact on the environment, its purging and recycling – reutilization [6].

3. THE ENERGETIC POTENTIAL OF COOLING WATER WITHIN THE CONTINUOS STEEL CASTING TECHNOLOGICAL PROCESS

The heat emerging through cooling water it is energetically considered loss of energy. The process of energy transformation are analysed by the use of actual energetic balance which constitutes an extremely important tool for the consumers offering useful information concerning ,[5] :

- diminishing energy consumption;
- evaluation potential of renewable reusable energy resources;
- setting into evidence the useful consumptions and energy losses within the analyzed network.

In order to setting into evidence the energetic potential of the cooling water aiming at evaluating the reusable energy resources potential, a case study of the cooling water with the continuous steel casting process will be presented.

The energetic balance for the technological line for elaboration, secondary treatment and continuous steel casting process contains three distinct large equipment ,[3]:

1. AC electric arc furnace;
2. Installation LF for secondary treatment of steel;
3. Installation TC for continuous steel casting.

For finding the energy lost with cooling water, measurements of flow rate and water temperature were required at the input and output for each installation of the analyzed contour.

3.1. AC electric arc furnace -the energetic potential of cooling water at the AC

The industrial water used for cooling the following elements of the electric furnace: wall cooling panels, furnace arch, gas exhaust bend, short line, power transformer and auxiliary equipment.

The heat lost with the cooling water is calculated with relation, [1]:

$$W_{cw} = \frac{\rho \cdot D_v \cdot c \cdot \Delta t \cdot \tau}{3600} [kWh / campaign] \qquad (1)$$

where: ρ – water density, [kg/m^3];
D_V – water flow rate,[m^3 /h];
c – water specific heat,[kJ/kg ^{0}C];
Δt - water temperature increase, [^{0}C];
τ - working campaign time, [h].

The heat lost with cooling water W_{cw} is related to both working time and the main product unit, the ton of liquid steel produced respectively .

In figure 2 the Sankey diagram is presented, whence it results that the most significant heat losses of the furnace are given by the heat lost with the gases exhausted W_g = 21,78% and by the heat lost with the cooling water W_{cw} = 12,49%. The losses with the cooling water represents a quantitatively large potential, [3]: W_{cw} = 124,87 MWh/working campaign ≈ 25 ÷35 GWh/year.

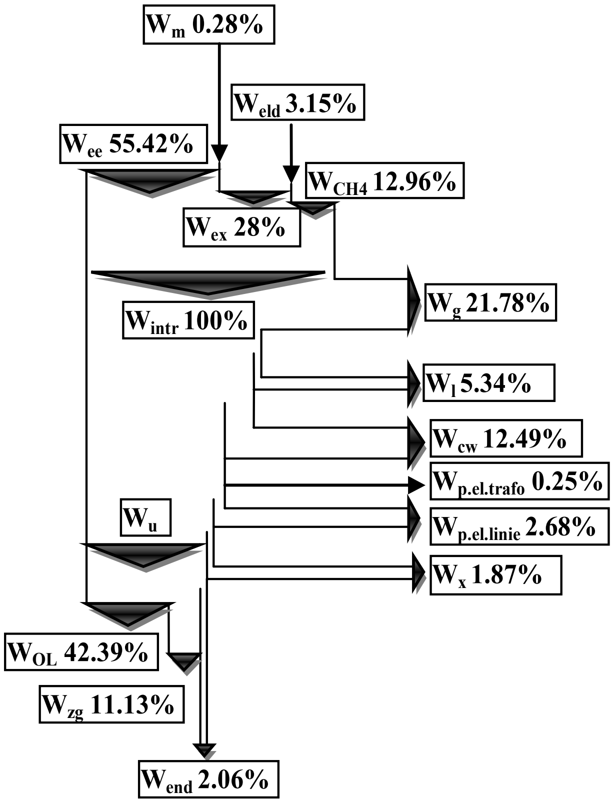

Fig. 2. Sankey diagram for AC arc type electric furnace [3].

3.2. Energetic potential of the cooling water within the secondary treatment installation of steel - LF

The cooling system of LF furnace: furnace arch and electrode holder beam – short line. In this case the amount of energy lost through the cooling water is 7,89% of the total energy consumed by the LF furnace, corresponding to a value [3]:

W_{cw} = 44,68 MWh/working campaign ≈ 9 ÷ 14,6 GWh/year.

3.3. The energetic potential of cooling water from the continuous casting TC equipment

The continuous casting equipment is provided with 5 casting lines. The industrial water cooling of the components is effected through a primary cooling circuit and a secondary circuit. The primary cooling circuit has the function to dissipate the heat transferred by the liquid steel to the copper tube of the crystallizer during pouring and water is recirculated in a closed loop. The spray cooling circuit or secondary circuit has the role of cooling the semi-finished castings just as they emerge from the crystallizer thus hastening the complete solidification of the semi-finished cross – section. The cooling water of this circuit is dissipated into atmosphere as steam and hot air, [3].

Table 2. presents the values of cooling water flow rate and temperature from the continuous casting process:

Table2.

Colling water flow-rate and temperature from the continuous casting,[3].

Nr.	Size	Symbol	UM	Value
1.	Colling water flow rate	D_V	m^3 /h	82
2.	Input temperature of cooling water	$t_{cw}^{`}$	^{0}C	19,5
3.	Output temperature of cooling water	$t_{cw}^{``}$	^{0}C	24,2

The heat lost with cooling water in the crystallizer, relative to the working time campaign is calculated with the relation [2]:

$$W_{cw} = \frac{n \cdot c \cdot \rho \cdot D_V \cdot \Delta t \cdot \tau}{3600} [kWh/camp] \qquad (2)$$

where : n = 5 number of pouring (casting lines)

In figure 3 with Sankey diagram it results that the cooling water of crystallizer represents only 5,44% of the heat contained of the poured steel and has the value, [3]:

W_{cw} = 28.627,69[MWh/working campaign] ≈ 6÷ 8 GWh/year

3.4. The energetic potential of cooling water from the continuous casting technological line

The energetic balance of the whole technological line presented in figure 4 shows the amount of energy losses related to the total energy consumption entered the general balance circuit.

In table 3 presents the total heat lost with the cooling water from the continuous casting technological line.

As a whole the total energy lost with the cooling water all along the casting line of steel represents 14,81% of the total energy cost of value, [3]:

W_{cw} = 198,19 [MWh/working campaign] ≈ 40 ÷ 60 GWh/year.

Table 3.
The total heat lost with the cooling wate, [3].

Nr	The title of balance components	Symbol	kWh/campaign	kWh/ton of steel	%
1.	Heat lost with AC cooling water	W_{cwCA}	124877,1	109,2	9,33
2.	Heat lost with LF cooling water	W_{cwLF}	44685,6	39,1	3,34
3.	Heat lost with TC cooling water	W_{cwTC}	28627,70	25,0	2,14
$W_{cooling\ water}$			198190,4	173,3	14,81

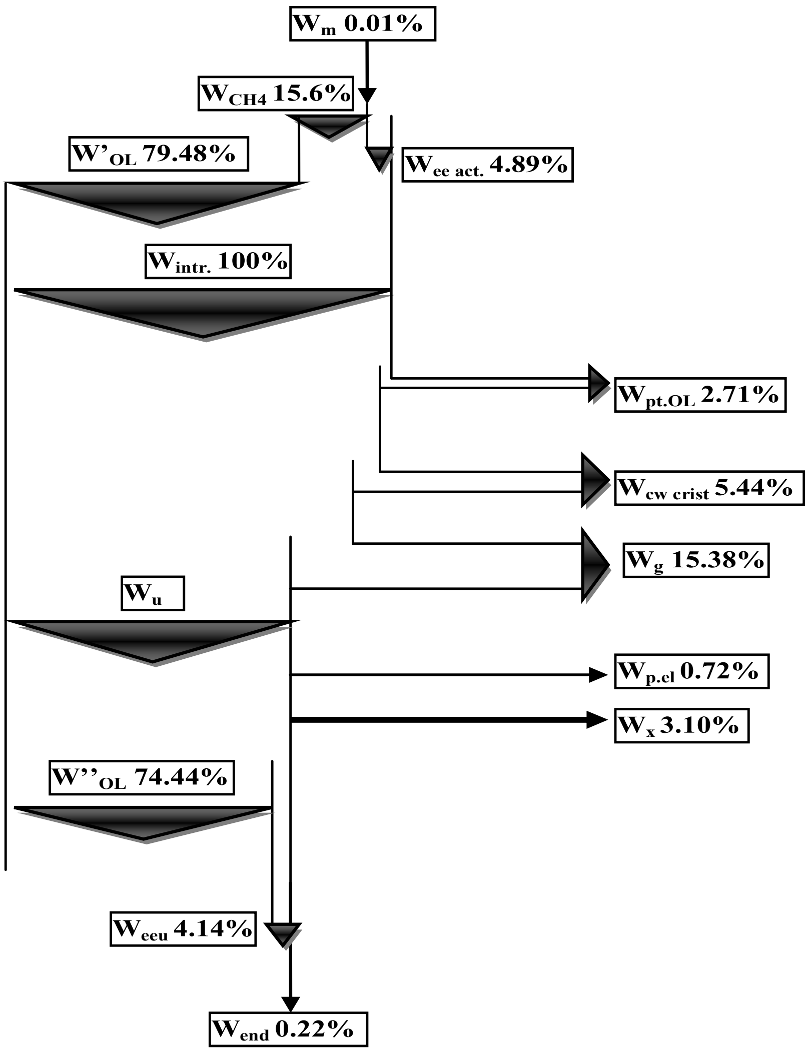

Fig. 3. Sankey diagram for the continuous casting equipment TL, [3].

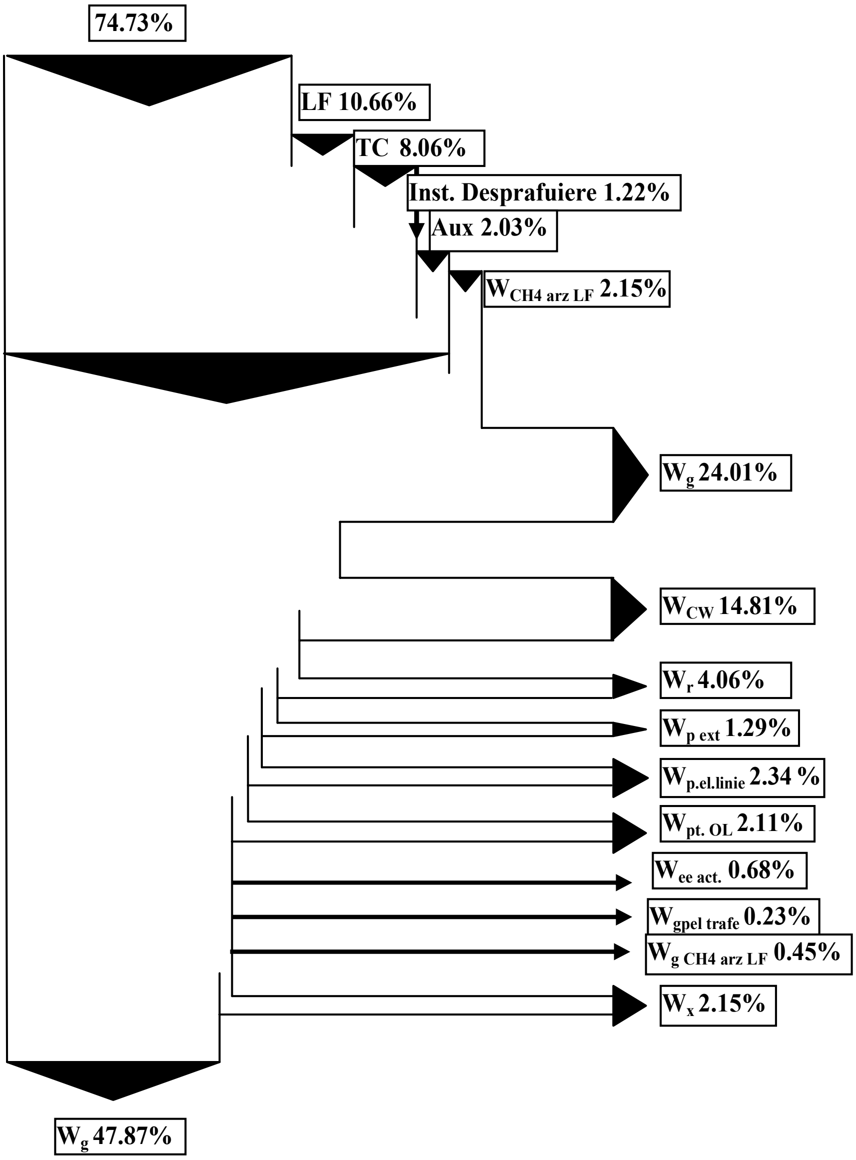

Fig 4. Sankey diagram. Total energetic balance, [3]

4. CONCLUSIONS

The secondary energy resource consisting of the cooling water resulting from the continuous steel casting technological system is considerable, from a quantitative point of view, $W_{\text{cooling water}}$ = 40 ÷ 60 GWh/year, as function of annual production representing 14,81% from the total energy consumption of the electric furnace equipment.

The amount of this secondary energy resource could be doubled or even tripled by including in the optimizing circuit, also the heat of gases resulting from the process (Wg =24,01%)s well as the residual heat contained in the semi-finished casting (W = 47,87%).

The thermal potential of water resulting from the cooling equipment of the continuous steel casting line is very low (t_{cw} =24 ÷ 40^0 C) so its utilization is not
attractive for useful applications (heating systems,
agriculture, various technological processes).

The optimization of the existing cooling systems by altering within admissible of increasing the output cooling temperature could heat to the substantial improvement of thermal potential of the resource.

Considering both the great amount of residual heat from the continuous steel casting line and the intermittent character of its operation the authors think that the most efficient way of turning to good account of these resources would be cogeneration (electric energy and thermal energy) by means of the equipment working on the basis of Rankine cycles with organic fluids.

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ANALIZA POTENŢIALULUI ENERGETIC AL APELOR DE RĂCIRE DE LA PROCESUL DE TURNARE CONTINUĂ A OŢELULUI

Rezumat: Scopul prezentei lucrări constă în evaluarea potenţialului energetic al apelor de răcire de la linia tehnologică de turnare continuă a oţelului . Fluxurile de energie aferente conturului de bilanţ sunt determinate pe baza măsurătorilor efectuate de autori. Se prezintă în mod intuitiv energia disipată, prin diagrame grafice Sankey, evidenţiindu-se ponderea importantă a căldurii pierdute prin apa de răcire.Lucrarea furnizează date utile pentru fundamentarea măsurilor de recuperare şi valorificare a resurselor secundare disponibile.

Gabriela Liliana DEAC, Ph.D. student, Technical University of Cluj-Napoca, Faculty of Materials Science and Engineering , Department of Environmental Engineering, gabinect@yahoo.com, Office Phone: 0264-401720

Cristina Daniela HORJU-DEAC, lect.Ph.D., Technical University of Cluj-Napoca, Faculty of Materials Science and Engineering, Department of Environmental Engineering, ddcristina@hotmail.com, Office Phone: 0264-401720

Ioan BIRIŞ, Professor, Ph.D. Technical University of Cluj-Napoca, Faculty of Materials Science and Engineering, Department of Environmental Engineering, ioanbiris11@yahoo.com, Office Phone: 0264-401720

Tiberiu RUSU, Professor, Ph.D. Technical University of Cluj-Napoca, Faculty of Materials Science and Engineering, Department of Environmental Engineering and Entrepreneurship for Sustainable Development, **tiberiu.rusu@sim.utcluj.ro**, Office Phone: 0264-401206