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PRIMARY ENERGY SAVING IN SELECTED TEXTILE INDUSTRY PROCESS

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ABSTRACT
Energy consumption in textile industry processes differ significantly. Steam pressing process as final operation in textile industry demands significant quantities of low pressure dry saturated steam. In this paper basic process is analysed and two options for primary energy saving are proposed. In both cases waste heat of flue gases is reused, once for condensate preheating and after that for combustion air preheating. Proposed schemes resulted in primary energy saving of 6,5% and 7,8% respectively.
Keywords: steam pressing, saving schemes, primary energy saving.

1. INTRODUCTION
Energy management is an integral part of industrial process overall efficiency. Benefits of increased energy efficiency are lower cost of product and at the same time decreased environmental impact [1]. In this paper energy consumption of selected textile process is analysed. Steam pressing can be encountered in textile industry as final operation in clothing industry as well as in other fields of textile industry where smooth surface of fabrics is needed.
Steam pressing, accomplished through electric steam presses and electric steam tables requires low pressure steam, electric energy, compressed air, vacuum [2].

2. ENERGY ANALYSIS OF BASIC PROCESS
In basic process heat energy for steam pressing process is supplied through low pressure dry saturated steam produced in natural gas fueled boiler (Fig. 1.). This steam is used for steam pressing in three technological sections gentlemen shirts, ladies' blouses and babies wear. Plant operates τ=5256 hours yearly. Total quantity of steam $D_S = 320\ \mathrm{kg/h}$ with pressure $p_S = 6$ bar and temperature $t_S = 158°\mathrm{C}$ produced in boiler is then reduced to pressure $p = 4$ bar and temperature $t = 143°\mathrm{C}$. Natural gas is used as primary energy source with lower heating value of $H_L = 35507{,}3\ \mathrm{kJ/m^3}$, and with composition $CH_4 : C_2H_6 : C_3H_8 : C_4H_{10} : C_5H_{12} : CO_2 : N_2$=98,05 : 0,36 : 0,12 : 0,05 : 0,01 : 0,85 : 0,56.

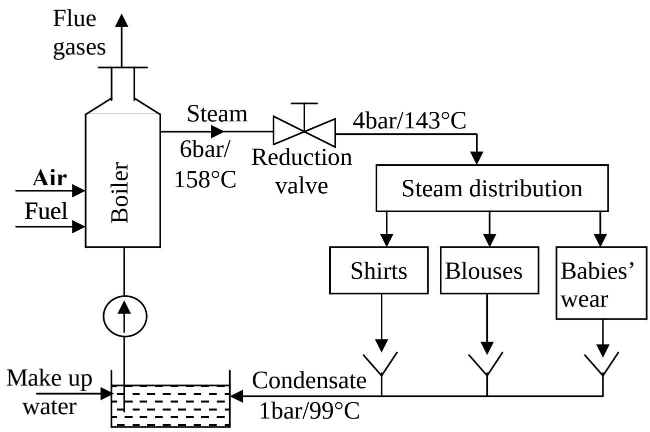

Figure 1. Scheme of basic steam pressing process

Volume and content of flue gases can be calculated from stoichiometric relations (table 1.).

Table 1. Volume of flue gases and its constituents

	Air, m^3/m^3_{FUEL}		Flue gases, m^3/m^3_{FUEL}				
Constituent	$V_{a\text{-}st}$	V_a	V_{CO_2}	V_{H_2O}	V_{N_2}	V_{O_2}	V_{FG}
Volume, m^3/m^3_{FUEL}	9,5	11,4	1,002	2,01	9,01	0,40	12,42
Part, %	-	-	8,1	16,2	72,5	3,2	100

As seen in Fig. 1. waste heat of condensate is already reused. From technological reasons 60% of condensate ($t_C = 99°C$) can be reused, while remaining quantity of feed water ($t_W = 15°C$) is covered with fresh water. Assuming adiabatically mixing of these flows, the mixture temperature is:

$$t_m = \frac{D_C \cdot t_C + D_W \cdot t_W}{D_S} = 65°C \qquad (1)$$

Primary energy consumption for basic process (Fig. 1.) can be calculated from boiler balance with boiler efficiency $\eta_B = 88\,\%$ and enthalpies of dry saturated steam and boiler feed water $h_S = 2757$ kJ/kg and $h_B = 274{,}1$ kJ/kg:

$$V_F = D_S \cdot \frac{h_S - h_B}{\eta_B \cdot H_L} = 25{,}43\ \mathrm{m^3/h} \qquad (2)$$

3. PRIMARY ENERGY SAVING OPTIONS IN STEAM PRESSING PROCESS

Remaining option for primary energy saving is flue gases waste heat recovery. There are two options: first is for preheating of feed water and second for preheating inlet air needed for combustion in the boiler.

3.1. Flue gases heat recovery for condensate preheating

Flue gases can be reused for condensate preheating if economizer is added to basic scheme (Fig. 2.) [3].

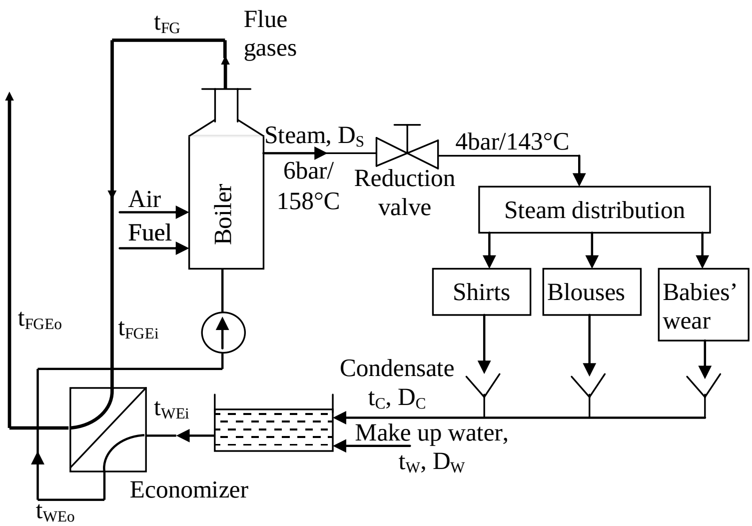

Figure 2. Flue gases heat recovery for feed water preheating

Heat balance for economizer can be set as follows:

$$V_F \cdot V_{FG} \cdot c_{pFG} \cdot \left(t_{FGEi} - t_{FGEo}\right) = D_S \cdot c_{pW} \cdot \left(t_{WEo} - t_{WEi}\right) = V_F \cdot V_{FG} \cdot c_{pFG} \cdot \left(t_{FGEi} - t_{WEi}\right) \cdot \eta_{ECO} \qquad (3)$$

with fresh water temperature $t_W = 15°\text{C}$ and feed water inlet temperature $t_{WEi} = t_m = 65°\text{C}$ (see equation (1)), efficiency of economiser $\eta_{ECO} = 85\%$ [4, 5], specific heat of water and flue gases $c_{pW} = 4{,}187\ \text{kJ/kgK}$, $c_{pFG} = 1{,}379\text{kJ/m}^3\text{K}$ (calculated upon content of flue gases constituents and their specific heats for temperature $t_{FG} = 204°\text{C}$ [2]) temperatures of flue gases $t_{FGEo} = 85{,}85°\text{C}$ and feed water $t_{WEo} = 103{,}41°\text{C}$ are calculated. Heat recovered from flue gases in economiser is:

$$Q_{ECO} = V_F \cdot V_{FG} \cdot c_{pFG} \cdot \left(t_{FGEi} - t_{FGEo}\right) = 51459{,}54\ \text{kJ/h} \qquad (4)$$

This heat equals consumption of primary energy source i.e. saving of natural gas in quantity ΔV_{ECO}:

$$\Delta V_{ECO} = \frac{Q_{ECO}}{H_L \cdot \eta_B} = 1{,}65\ \text{m}^3/\text{h} \qquad (5)$$

Compared to fuel consumtion of basic process it gives 6,5% primary energy saving. On the year base with operation time $\tau = 5256$ hours total volume of saved natural gas is 8672 m^3.

3.2. Flue gases heat recovery for inlet air preheating

Next option for flue gases heat recovery is adding air preheater to basic scheme in order to preheat inlet air to boiler (Fig.3.) [3]. Heat balance for air preheater is:

$$V_a \cdot c_{pa} \cdot \left(t_{aAo} - t_{aAi}\right) = V_a \cdot c_{pa} \cdot \left(t_{FGAi} - t_{aAi}\right) \cdot \eta_A = V_{FG} \cdot c_{pFG} \cdot \left(t_{FGAi} - t_{FGAo}\right) \qquad (6)$$

and enables calculating of air outlet t_{aAo} and flue gases outlet t_{FGAo} temperatures with air preheater efficiency $\eta_A = 90\%$ [4, 5], specific heat of air $c_{pa} = 1{,}29\ \text{kJ/m}^3\text{K}$, and specific heat of flue gases c_{pFG}, kJ/m^3. These values are $t_{aAo} = 185{,}6°\text{C}$ and $t_{FGAo} = 61{,}8°\text{C}$.

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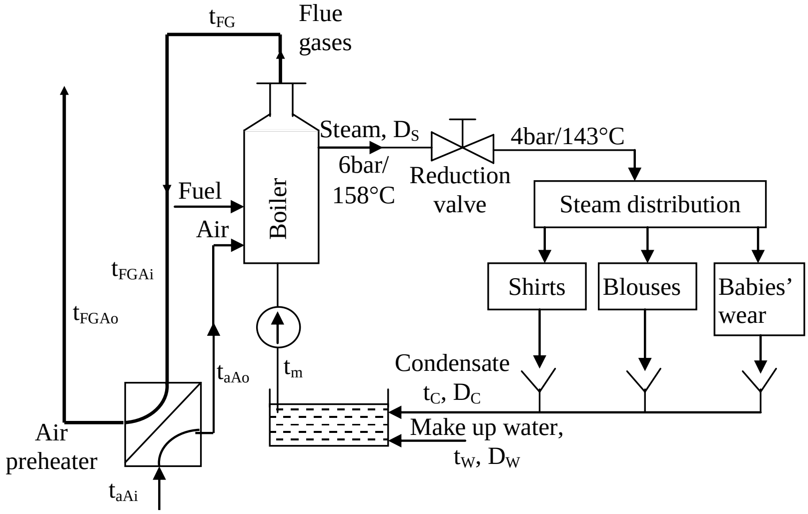

Figure 3. Flue gases heat recovery for combustion air preheating

Heat exchanged in air preheater is:

$$Q_{AP} = V_F \cdot V_{FG} \cdot c_{pFG} \left(t_{FGAi} - t_{FGAo} \right) = 61930{,}03 \text{ kJ/h} \qquad (7)$$

and is energy equivalent of primary energy source saving ΔV_{AP} :

$$\Delta V_{AP} = \frac{Q_{AP}}{H_L \cdot \eta_B} = 1{,}98 \text{ m}^3\text{/h} \qquad (8)$$

This value expressed as percentage of primary energy source consumption V_F from equation (2) is 7,8% and yearly with $\tau = 5256$ hours this yields to 10407 m^3 of saving of natural gas.

4. CONCLUSION

Energy management of industrial processes is important part of their final economical value on competitive market. Analysed process of steam pressing in textile industry pointed possible options for energy saving. Proposed schemes are concentrated on waste heat of flue gases recovery satisfying basic condition that output quality of product is matter of success on market and must not be decreased. Considering this fact proposed energy saving options use existing waste heat potential in technologically and economically acceptable manner. Achieved primary energy source saving are between 6,5% and 7, 8% improving overall effectiveness of steam pressing process and decreasing ecological impact of process.

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