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Analysis of Energy Consumption in Professional Laundry Care Process

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In comparison with washing at home the professional laundry care process in commercial laundry premises presents an environment-friendly alternative. Experience from up-to-date premises with capacity up to 5000 t of linen p. a. shows that only from 5 to 6 L of water are necessary for each kg of linen. In case of washing at home the water requirement exceeds 20 L/kg. The same tendency can be observed in energy consumption as well as dosing rate of detergents. However, on the annual basis, the professional laundry premises represent large energy and water consumer, where the costs of energy and water supplies make up important items of total costs.
Laundry premises owners are forced by current commercial environment to drive down operational costs and hand in hand with it also the price of their services. These days the laundry service does not mean just the laundry washing itself but also the logistics and complex service including clothes and linen renting.
A way to drive down operational costs is the whole process optimization and integration of various pieces of equipment such as heat exchangers for effluent water waste heat utilization. However, the basic condition for good results is that the solution has to be hand-tailored for the specific premises.

1. Introduction

General structure of industrial laundry premise is shown on Figure 1. This way designed premise is able to process wide range of linen such as dirty working clothes, linen from hospitals, hotels and restaurants etc. A ratio of flat linen which is usually processed by continuous batch washer (CBW), system dryer and ironer often exceeds 70 %. That's why this paper is focused on these key devices.

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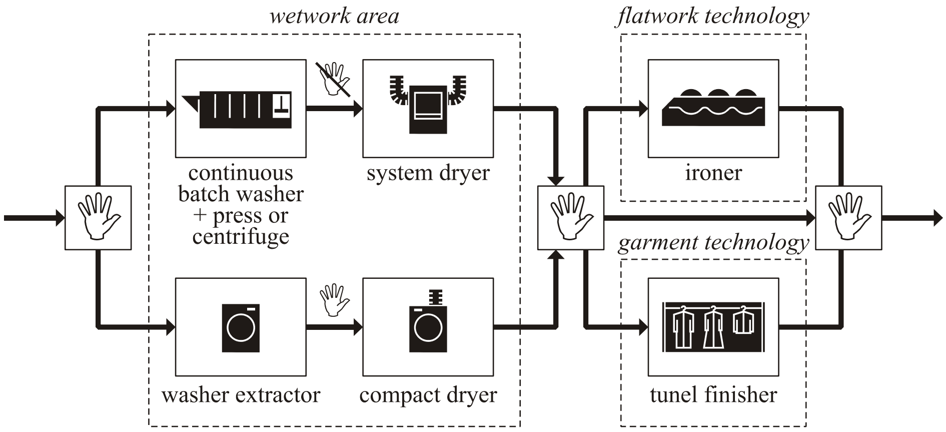


Figure 1: General structure of industrial laundry premise

CBWs are dominant water consumers and significant heat consumers, however, from the heat consumption point of view, dryers and ironers are the main heat consumers in the overwhelming majority of high capacity laundry premises. It is because of the fact that in CBWs water used for washing is only heated (see Figure 2) whilst in drying devices the moisture absorbed into linen has to be evaporated.

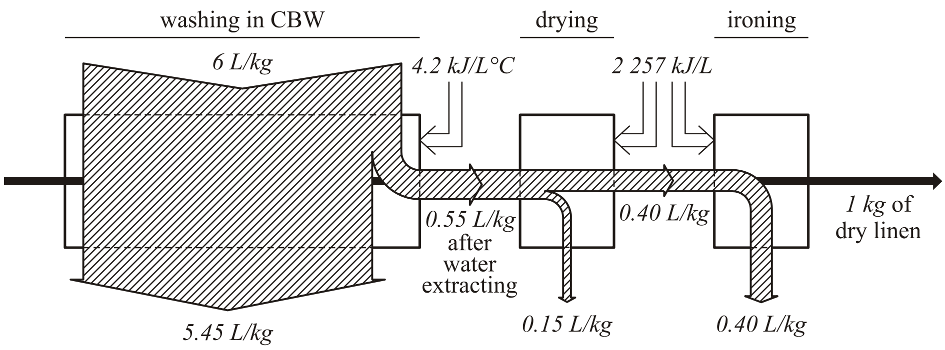


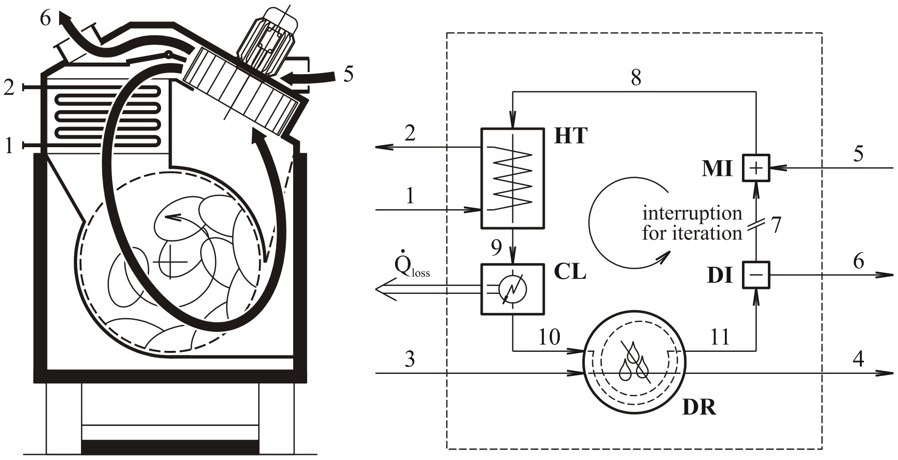
Figure 2: Water flow diagram of basic professional laundry care operations and their theoretical specific heat consumptions

To water flows the theoretical energy consumptions can be easily added via using specific heat capacity and specific evaporation heat of water. But, unfortunately, the real energy consumptions considerably differ from the theoretical values. To specify heat losses which make great deal of required energy the computational modeling and experimental measuring approach can be used.

2. Computational modeling

In order to find out the main factors which influence the energy intensity of the process computational models of the key devices (CBW, dryer and ironer) have been done. One

for all, following Figure 3 provides model design of steam heated tumble dryer compared to real machine disposition.
All mathematical models are based on unit operations and via heat and mass balances computation they are able to figure out the response to input data with satisfactory degree of reliability.



input streams { 1 ... steam; 3 ... wet linen; 5 ... fresh air }
output streams { 2 ... steam condensate; 4 ... linen with residual moisture; 6 ... used drying air; ($\dot{Q}_{loss}$ ... heat losses) }

unit operations:
HT ... heating
CL ... cooling (heat losses)
DR ... drying
DI ... dividing
MI ... mixing

Figure 3: Computational model design of steam heated tumble dryer with recirculation of drying air in comparison with real machine disposition

3. Measurement of drying devices characteristics

Generally, experimental measurement is very useful for individual device optimizing and also very important for verifying computational models. There are two ways to measure the characteristics of drying devices (i.e. tumble dryers and ironers).
The first one is called direct method. In this method the amount of energy (steam or gas) which enters the machine is directly measured and then it’s compared to evaporated water amount which can be quite easily found out via weighing the linen before and after a drying period. Unfortunately the measuring of consumed steam is very expensive and time demanding because it needs to install a steam flow meter and other equipment (at least filter and separator) for each dryer or ironer. A little bit easier situation is in the case of gas consumers (i.e. gas dryers).
The second way to measure the characteristics of drying devices is called indirect method. In this case properties of mixture of air and evaporated moisture from linen which are leaving the device are measured. The tracked quantities are velocity (flow rate), temperature and humidity, and they are measured by humidity/temperature and vane/temperature probes (as shows Figure 4) placed in output pipeline (e.g. stream

num. 6 on Figure 3). After elaborating data it’s possible to establish specific heat consumption and a drying capacity of the device. This method is much easier than the first one because the only preparation is to drill two holes with diameter of about 20 mm into the output pipeline which is very advantageous especially for mobile measurement.

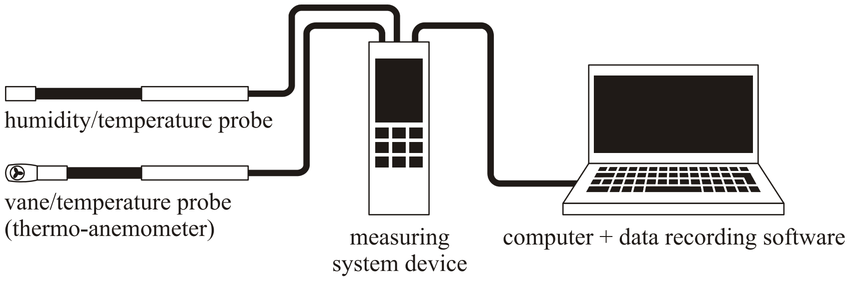


Figure 4: Measuring equipment for indirect method to establish characteristics of drying devices

4. Energy efficiency and capacity of key devices

Two most important parameters of dryer and ironer are real specific energy consumption and drying capacity. The first one represents amount of energy (usually states in amount of certain pressure steam) needed to evaporate a kg (or a L) of moisture. The smaller the value, the higher the energy efficiency of the device and the better the device.

Drying capacity represents amount of water (moisture in linen) which a device is able to evaporate per minute. Obviously, the higher the value, the better the device and the higher the capacity of the whole laundry premise. Values of both the parameters usually can be found in technical documentation of each device but in the real premise they often differ from values provided by manufacturer. The reasons of this fact are wrong settings, maintenance and operation of the machine. Sometimes are the values provided by manufacturer just too optimistic.

Figure 5 shows how important is to take care about dryer’s filters to keep the best efficiency of the machine and also, generally, how real specific energy (or steam or gas) consumption of drying machines can be divided into three parts as follows:

- energy used for water evaporation (equals to theoretical specific energy consumption) – that’s the effective part,
- energy used for heating of air
- and energy required to cover radiation losses.

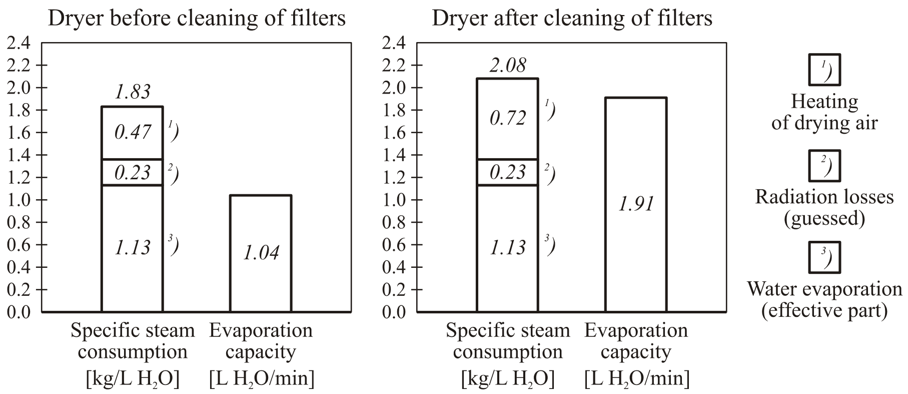


Figure 5: State of a dryer before and after cleaning of filters

Energy intensity of washing process is given by amount of energy used for heating washing water. The basic condition for low energy consumption is well done water requirement optimization because the lower water amount the lower energy needed to heat it. Heat exchanger can heat incoming fresh water by hot waste water and this way it can significantly lower the heat consumption (see Table 1).

Table 1: Response of specific energy consumption to heating washing water by ΔT

temp. difference ΔT [°C]	specific water requirement [L/kg$_{\text{of linen}}$] 6	8	10
75	*1890*	*2520*	*3150*
60	*1512*	*2016*	*2520*
45	*1134*	*1512*	*1890*
30	*756*	*1008*	*1260*

[kJ/kg$_{\text{of linen}}$]

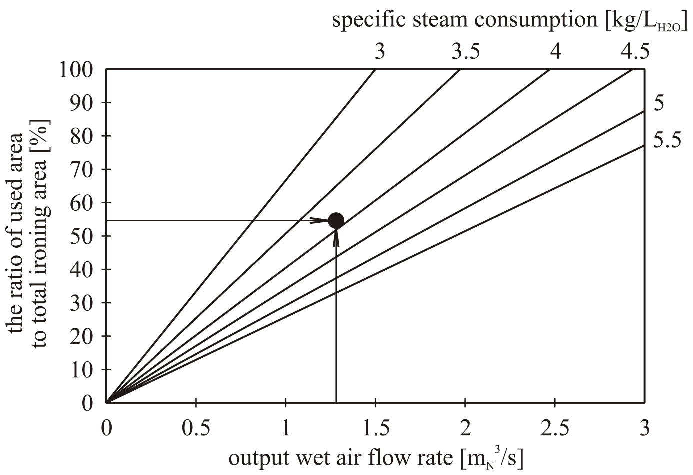


Figure 6: Relation of steam consumption of ironer to ironing conditions

In professional laundry care process there are many factors which influence capacity and energy intensity. One of the very important is also, generally speaking, ratio of usage of the machine. For example, Figure 6 shows how the ratio of usage of ironing area influences ironer's steam consumption.

5. System approach

Usually, well optimized energy consumption of each stand-alone device doesn't make the lowest amount of required energy on the whole. It is the same as it is not guaranteed that the best individual players always make the best team. So a way to decrease more the energy consumption is to look at the process as on the whole and utilize energy of all available hot streams within the bounds of profitable solution.

The mathematical models are about to be implemented into in-house software package which will allow using existing user friendly interface and general methods of the system. The concept of the software is base on computational approach presented in (Tous M. et al, 2009).

6. Conclusion

Future work will continue with improving mathematical models and their implementation into overall computational system which will be able to help to understand all relationships in process of professional laundry care and which could analyze advantages and disadvantages of up-to-date approaches as follows:

- usage of centralized vs. distributed heat supply,
- integration of renewable sources of energy (solid biomass, liquid bio-fuels) – "green" laundry concept,
- integration of unconventional solutions (cogeneration, heat pumps).

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