Optimizing reduced energy resources to meet finishing requirements

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1. Abstract

Energy utilization in traditional finishing processes has to be optimized through the use of innovative technologies. This article describes how energy costs are incurred and how with simple means and methods maximum energy utilization can be achieved through the use of innovative technologies in traditional finishing processes. Dryer configurations, minimum application processes, measuring and control technology and fabric examples are described.

2. Introduction

Discussing dwindling resources is no longer relevant today. No matter how alternative energies are generated, we have to use less energy more effectively.

The parliamentary State Secretary at the German Federal Ministry for Economics and Technology, Dagmar Wöhrl, said during the opening of a congress last year: "Energy is the motor for economic growth and development worldwide. The conservative use of energy and raw materials is not only a major factor for climate protection, but also and more particularly, an important competitive advantage for companies and national economies. Using resources efficiently allows you to produce more cost-effectively than the competition.

The awareness that the best energy is the energy that is not used is gaining more and more significance, particularly in the light of the ever-increasing energy and raw material prices."

3. Where do costs occur, and how can they be measured?

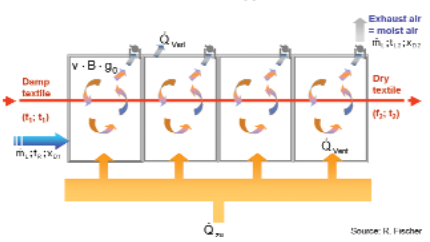
If we consider the stenter as one of the main driers used in textile finishing, then certain demands are made on this drier and its configuration.

Modern stenters today should

- Have a high drying capacity.
- Have good insulation.
- Have variable-frequency circulating air fans.
- Have variable-frequency exhaust air fans.
- Be equipped with high-efficiency motors for fans, drives and auxiliary motors.
- Have long-term lubrication for the chain and require minimum maintenance.
- Be equipped with measuring, control and regulating elements
- Have a heat recovery system.
- If necessary, have an exhaust air scrubber, and
- Have upline facilities to permit universal application.

If your stenter meets these requirements, you have already taken the first step in the right direction. If we now consider the classic stenter drying process [Fig. 1], we can see here how much heat energy is required to dry a damp textile.

The classic drying process (stenter)
Where do costs arise, and what type of costs?



Source: R. Fischer

[Fig. 1]

The damp textile web enters the stenter at production speed and is heated up. The water is vaporized and evaporates. The dried textile leaves the stenter with a certain residual moisture content and at a certain temperature.

The evaporated water is absorbed by the circulating air (=energy medium). Part of this moist air is drawn out of the machine as exhaust air and is replaced by fresh air. This fresh air has to be heated to drying temperature. The energy required to evaporate the water, heat up the fresh air and compensate the losses is supplied to the machine by the heater with the circulating air serving as energy medium. A small part of the energy is normally fed into the system by the rotating fan blades of the circulating air fans.

This can be expressed by the following formula [1]:

$$\boxed{\dot{Q}_{zu} = \dot{Q}_{PRO} + \dot{Q}_{FL} + \dot{Q}_{Verl} - \dot{Q}_{Vent}}$$

$\dot{Q}_{PRO}$ = Heat flow for the actual drying process with energy requirement for heating up textile and water, for evaporation of the water and for superheating the resulting steam to drying temperature
$\dot{Q}_{FL}$ = Heat flow for heating up the fresh air to drying temperature
$\dot{Q}_{Verl}$ = Heat loss flow, e.g. radiation via dryer walls and stenter chain
$\dot{Q}_{Vent}$ = Heat of friction of the fan blades, benefits the process (does not have to be provided by heating)

The process heat flow and the heat flow to heat up the fresh air are the most significant elements in the drying process. The importance of the heat flow for heating up the fresh air has already been described many times, so that here reference is made merely to citations [2-4] on the above subject.

The process heat flow is here the most important heat flow for which energy has to be input.

$$\boxed{\dot{Q}_{PRO} = \dot{Q}_T + \dot{Q}_{H_2O} + \dot{Q}_{Verd} + \dot{Q}_{Über}}$$

$\dot{Q}_T = \dot{m}_T \cdot C_T \cdot (t_2 - t_1)$	Heating up the textile
$\dot{Q}_{H_2O} = \dot{m}_{H_2O} \cdot C_{H_2O} \cdot (t_K - t_1)$	Heating up the water in the textile
$\dot{Q}_{Verd} = \dot{m}_{H_2O} \cdot \Delta h_v$	Evaporation of the water ($\Delta h_v = 2260$ kJ/kg)
$\dot{Q}_{Über} = \dot{m}_{H_2O} \cdot C_{p,D} \cdot (t_{Dü} - t_K)$	Superheating of the steam ($C_{p,D} = 2.0$ kJ/kg · K)

The specific energy consumption for each application can then be calculated using these formulae.

- Specific energy consumption per kg evaporated water.

$$q_{H_2O} = 3600 \cdot \frac{\dot{Q}_{zu}}{\dot{m}_T \cdot (f_1 - f_2)} [\text{kJ / kg H}_2\text{O}]$$

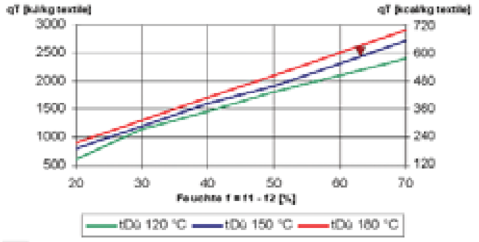
- Specific energy consumption per kg textile.

$$q_T = 3600 \cdot \frac{\dot{Q}_{zu}}{\dot{m}_T} [\text{kJ / kg Textil}]$$

From these calculation bases it is possible to determine the specific energy consumption per kg textile during the drying process in the stenter as a function of the water volume to be evaporated (the parameter is the drying temperature). [Fig. 2]

Specific energy consumption per kg textile for the drying process on the stenter as a function of the water volume to be evaporated (parameter is the drying temperature)

- 100% Co, 1.5 m, $t_{Dü}$ = 150°C, x_D = 15 vol.%



[Fig. 2]

- Example 1 f_1 = 70 %, f_2 = 8% q_T 2400 kJ/kg textile
- Example 2 f_1 = 40%, f_2 = 8% q_T 1250 kJ/kg textile

This specific energy consumption holds true for 100% Co, 200 g/m², 1.50 m wide.

tDü = 150°C, xD = 15 Vol%

Example 1 f_1 = 70% initial moisture content.
f_2 = 8% residual moisture content.
q_T 2400 kJ/kg textile.

Example 2 f1 = 40% initial moisture content.
f_2 = 8% residual moisture content.
q_T 1250 kJ/kg textile

This then gives an hourly energy consumption during the drying process of

$$\dot{Q}_{ZU} = \frac{60}{3600} \cdot q_T \cdot v \cdot B \cdot g_o$$

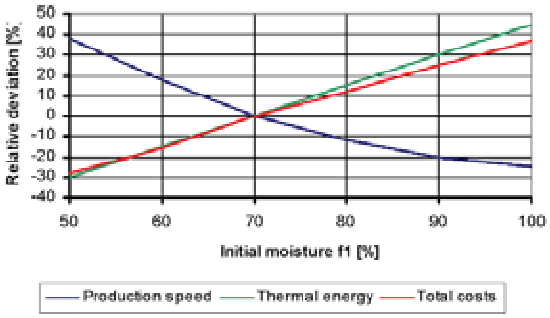
$$\dot{Q}_{ZU\ 1)} = \frac{60}{3600} \cdot 2400 \cdot 80 \cdot 1{,}5 \cdot 0{,}2 = 960 \text{ kW}$$

$$\dot{Q}_{ZU\ 2)} = \frac{60}{3600} \cdot 1250 \cdot 80 \cdot 1{,}5 \cdot 0{,}2 = 500 \text{ kW}$$

Savings with 40% f_1 Δ 460 kW

The enormous influence of the initial moisture content on the drying process is shown here again from a different perspective for emphasis.

Influence of initial moisture content on the drying process



[Fig. 3] shows the effect of a variation in the initial moisture content.

[Fig. 3] shows the effect of a variation in the initial moisture content. Starting point here is 70%. A reduction in the initial moisture content results in an increase in the production speed and a reduction in the energy consumption and production costs. An increase naturally results in the opposite effect. Overall costs and thermal energy have practically the same percentage relative deviation. In summary this means first of all: The greatest contribution to energy savings is made by a reduction in the initial moisture content. Wherever possible, alternative liquor application systems should be employed. The liquor application should be as low as possible, but as high as necessary.

4. Examples of cost reductions during the drying process to suit your needs

Example 1 Trouser fabric, 100% Co, 250 g/m², 1.52 m wide
(Range: 7F stenter + condensation hotflue)

- Step 1: Drying on the stenter
- Step 2: Curing on the hotflue

} Stain release process

1.	Initial moisture: 70 % Residual moisture: 8 % Temperature: 130/150 °C Fan speed: 1450 rpm	Heat energy: 674 kW with HR Electrical energy: 117 kW	53 m/min
2.	Initial moisture: 40 % Residual moisture: 8 % Temperature: 130/150 °C Fan speed: 1450 rpm	Heat energy: 658 kW with HR Electrical energy: 120 kW	94 m/min
3.	Initial moisture: 40 % Residual moisture: 8 % Temperature: 110/120 °C Fan speed: 900 rpm	Heat energy: 392 kW with HR Electrical energy: 38 kW	54 m/min
	Savings at constant V [m/min]:	Heat energy: 41,8 % Electrical energy: 67,0 %	

In this example, only step 1 is considered, as step 2 is a process without water evaporation.

Drying process 1: Classic

Drying process 2: Reduced initial moisture content

Drying process 3: Reduced initial moisture content and modified machine setting.

Example 2 Terry cloth, 450 g/m², 2.10 m wide,
30 m/min (1701 kg fabric/h)

A. "Customer" process

1	Dyeing and washing			
2.	Main dewatering	f_1	=	93 %
3	Wet in wet	f_1		112 %
	(4% softener application)	$G_{softener}$	=	68 kg/h
4	Air passage			
5.	Main dewatering	f_1	=	90 %
	(remaining softener 2.4%)	$G_{softener}$		40,82 kg/h
	(loss of softener 1.6%)	$G_{softener}$	=	27,22 kg/h
		$C_{softener}$	=	120 t/year (4400 h/year)
6	Drying			

Summary:
- with 1.50 EUR/kg 180,000 EUR/year product down the drain
- Sewage pollution!

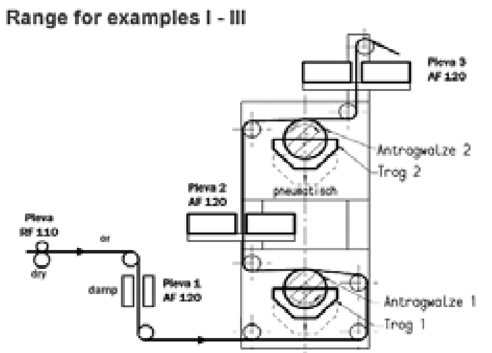
Example 3 Terry cloth, 450 g/m², 2.10 m wide,
30 m/min (1701 kg fabric/h)

C. Minimum application on wet fabric

1.	Dyeing and washing			
2.	Main dewatering	f_1	=	93 %
3.	Minimum application 2 x 3%	f_1	=	99 %
4.	Air passage	not required		
5.	Main dewatering	not required		
6.	Drying	f_1	=	99 %
		Additional drying costs 35,402 EUR/year		

Summary:
- Possible! No water bag, no loss of softener, no waste water pollution.
- 180,000 EUR/year savings
  - 35,400 EUR/year additional drying costs
  144,600 EUR/year savings

(Δf = 19%) Additional costs for drying 73,022 EUR/year (better than 180,000 EUR softener loss).



[Fig. 4] shows the range configuration for the wet-in-wet process.

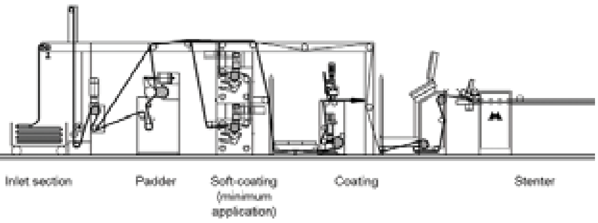
Example 4 Denim finishing

A. One-sided application (1x finishing liquor), only 25% not 70% ⇨ Saving
B. Two-sided application (2x same liquor), only 40% not 70% ⇨ Saving
C. Two-sided application (2 different liquors in 1 passage)
  A. e.g.: 1. side pigment dyes + 2nd side finishing } Saving +
  B. e.g.: 1. side hydrophobic + 2nd side hydrophilic finishing } New effects

Summary:

- Create new ideas
- Be able to more than the rest
- Save drying steps at the same time
- Put need to your benefit.

[Fig. 5] shows a soft-coating production range.



[Fig. 6] shows a stenter inlet section with various upline elements.

($\Delta f = 6\%$) Additional costs for drying 35,402 EUR/year.

5. Final considerations

This article is intended to show where the problems lie during drying, and how maximum energy utilization can be achieved with simple means and methods through the use of innovative technologies in traditional finishing processes. Energy efficiency is a step in the right direction. What can be avoided doesn't need to be disposed of, and what isn't applied doesn't need to be dried.

Our motto is "Put need to your benefit".

Redesign dryers electrically (use of: frequency controllers, high-efficiency motors, measuring instruments). Reconcile economy and ecology (use affordable technology to reduce energy consumption and costs, reduce the waste water).

Use our resources conservatively, because our children's children will also need energy.

Symbols used in formulae

atro	Absolutely dry (water content = 0)	
B	Width of the textile web	[m]
C_{H_2O}	Specific thermal capacity of water	[4.2 kJ/kg K]
C_{HD}	Specific thermal capacity of steam	[2.0 kJ/kg K]
C_T	Specific thermal capacity of textile	[1.4 kJ/kg K]
f_1	Initial moisture content (ingoing moisture)	[% w/w]
f_2	Residual moisture content (outgoing moisture)	[% w/w]
Δf	Difference in moisture content	[% w/w]
g_o	Specific weight of fabric web, referred to atro	[kg/m²]
$G_{Softener}$	Softener consumption	[kg/h]
Δh_v	Specific evaporation heat of water	[2260 kJ/kg]
$\dot{m}_{H_2O}$	Mass flow of water	[kg/h]
$\dot{m}_L$	Mass of fresh air	[kg/h]
$\dot{m}_T$	Mass flow of textile	[kg/h]
mWR	With heat recovery	
n	Fan speed	[rpm]
q_{H_2O}	Specific energy consumption per kg water	[kJ/kg H_2O]
q_T	Specific energy consumption per kg textile	[kJ/kg textile]
$\dot{Q}_{FL}$	Heat flow to heat up the fresh air	[kW, kJ/h, kcal/h]
$\dot{Q}_{H_2O}$	Heat flow to heat up the water	[kW, kJ/h, kcal/h]
$\dot{Q}_{PRO}$	Heat flow for the whole process	[kW, kJ/h, kcal/h]
$\dot{Q}_T$	Heat flow to heat up the textile	[kW, kJ/h, kcal/h]
$\dot{Q}_{Vent}$	Frictional heat flow of the fan blades	[kW, kJ/h, kcal/h]
$\dot{Q}_{Verd}$	Heat flow to evaporate the water	[kW, kJ/h, kcal/h]
$\dot{Q}_{Verl}$	Heat flow loss	[kW, kJ/h, kcal/h]
$\dot{Q}_{Über}$	Heat flow to superheat the steam	[kW, kJ/h, kcal/h]
$\dot{Q}_{zu}$	Heat flow input	[kW, kJ/h, kcal/h]
t_1	Inlet temperature of the textile fabric web	[°C]
t_2	Outlet temperature of the textile fabric web	[°C]
t_{DO}	Nozzle outlet temperature	[°C]
t_K	Cooling limit temperature	[°C]
t_{L2}	Temperature exhaust air	[°C]
t_R	Room temperature	[°C]
v	Production speed	[m/min]
x_{D1}	Steam content of fresh air	[%]
x_{D2}	Steam content of exhaust air	[%]

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