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Analysis of Energy Consumption in Woven Fabric Production

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Abstract
One of the most important factors that affect the cost of a woven fabric is the energy cost. In this study, general information about the energy types and levels that are used during woven fabric production has been given, and an energy analysis of a chosen weaving mill has been conducted. A new theoretical approach has been developed for determining the specific energy consumption of selected woven fabric. The energy consumption of a particular woven fabric produced in the chosen weaving mill has been calculated using the equations given, and the results obtained have been compared with data given in literature.

Key words: *woven fabric, energy consumption, specific energy consumption.*

Introduction

Weaving mills are one of the subsections of the textile and apparel industry that use yarn as raw material and produce woven fabrics by processes such as winding, warping, sizing, drawing in (weaving preparation) and weaving [1, 2]. Competing with other mills in the same field is dependent on producing high quality woven fabrics in time for a reasonable price. The cost of a woven fabric consists of several cost factors, such as the raw material, the energy or power cost, the labour cost, the auxiliary material cost, the capital cost etc. The share of the cost factors in the total cost of a woven fabric changes according to the properties of the fabric, operational properties of machines used, the economic situation of the weaving mill and the country in which the fabric is produced [3 - 5].

Table 1 illustrates cost factors which make up the total cost of woven fabric produced from both ring and open-end rotor yarn with the same fineness for selected countries. Shares of the cost factors in the total fabric cost can also be seen from the table. One of the most important cost factors affecting the total cost is that of energy, especially for countries such as China, India and Turkey.

Various studies have been done to determine the energy cost and energy consumption of woven fabrics. Kaplan [3] studied cost factors which make up the total product cost for the textile industry, including spinning, weaving, finishing and the product cost of the chosen woven fabric, using empirical formulas with specific operating conditions, and selected machine parameters were estimated. Cost calculation of derived woven fabric was conducted by Kaplan and Koç [7]. Özgan [8] and Bilge [9] investigated cost factors affecting the total cost of woven fabric, explained the calculation of each cost factor, such as the raw material, labour and energy, and tried to calculate the total cost of a given woven fabric. Cost factors affecting the total cost of woven fabric and the costs of different types of woven fabrics with changing machine parameters were also evaluated by Kuşçuoğlu [10]. The International Textile Manufacturer Federation [6] has made a comparison of the manufacturing costs of textile processes, including spinning, texturing, weaving and knitting, in their yearly technical report.

The report investigated energy management practices amongst the textile industries of several countries as well as the specific energy consumption for branches of the textile industry, including weaving and finishing [11]. It was specified by Visvanathan et al [12] that the specific electrical energy used for woven fabric manufacturing changes between 5.7 and 5.8 kWh/kg, whereas the specific thermal energy is in the range of 2.2 - 25 kJ/kg. The electrical energy consumption for

Table 1. *Cost factors affecting the cost of woven fabric in $/m and share in % given in bracket (2006) [6].*

Cost factors	Brazil		China		India		Italy		Korea		Turkey		USA	
	Ring	OE	Ring	OE	Ring	OE	Ring	OE	Ring	OE	Ring	OE	Ring	OE
Raw material	0.258 (36)	0.317 (48)	0.342 (46)	0.437 (58)	0.205 (33)	0.253 (43)	0.249 (25)	0.308 (34)	0.258 (35)	0.320 (45)	**0.270 (37)**	**0.337 (48)**	0.232 (28)	0.280 (38)
Labour	0.037 (5)	0.028 (4)	0.014 (2)	0.011 (1)	0.017 (3)	0.014 (2)	0.324 (32)	0.253 (28)	0.123 (17)	0.101 (14)	**0.079 (11)**	**0.059 (8)**	0.222 (27)	0.165 (22)
Energy	0.063 (9)	0.048 (7)	0.100 (14)	0.077 (10)	0.119 (19)	0.091 (15)	0.129 (13)	0.098 (11)	0.076 (10)	0.058 (8)	**0.082 (11)**	**0.059 (8)**	0.057 (7)	0.044 (6)
Auxiliary material	0.045 (6)	0.046 (7)	0.053 (7)	0.056 (7)	0.071 (11)	0.079 (13)	0.074 (7)	0.082 (9)	0.068 (9)	0.074 (11)	**0.081 (11)**	**0.092 (13)**	0.053 (6)	0.054 (7)
Depreciation and interest	0.270 (38)	0.104 (29)	0.177 (24)	0.132 (18)	0.181 (29)	0.135 (23)	0.185 (18)	0.140 (15)	0.167 (23)	0.123 (17)	**0.172 (24)**	**0.129 (18)**	0.234 (28)	0.172 (23)
Waste	0.042 (6)	0.028 (4)	0.053 (7)	0.035 (5)	0.033 (5)	0.023 (4)	0.043 (4)	0.030 (3)	0.042 (6)	0.028 (4)	**0.045 (6)**	**0.031 (4)**	0.039 (5)	0.027 (4)
Total	**0.715 (100)**	**0.662 (100)**	**0.740 (100)**	**0.748 (100)**	**0.627 (100)**	**0.595 (100)**	**1.004 (100)**	**0.911 (100)**	**0.733 (100)**	**0.704 (100)**	**0.728 (100)**	**0.707 (100)**	**0.837 (100)**	**0.741 (100)**

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1 kg of woven fabric changes between 2.1 kWh/kg and 5.6 kWh/kg, as observed in the study of Tarakçıoğlu [13].

Another study dealing with energy conservation in the textile industry focused on the electricity consumption of each step of weaving processes [14]. Şenol [15] studied energy consumption and conservation in weaving preparation. Alpay [16] showed the calculation of energy consumption during basic weaving functions, such as shed opening, weft insertion, beating up in weaving machines and the computed energy consumption of each step with different production parameters.

In this study, general information about the type and level of energy used for manufacturing woven fabric is first given. An energy analysis is then conducted for the weaving mill chosen. In addition, a new theoretical approach has been attempted in order to calculate the total and specific energy consumption occurring during the manufacturing of the woven fabric selected. The total and specific energy needed for manufacturing the chosen fabric in the mill selected have been calculated using this approach, and the results obtained have been compared with data given in literature.

General energy consumption in weaving mills

As in other industries using machines during manufacturing, energy is the fundamental production factor for weaving mills. Energy is generally used for operating machines, air conditioning and illuminating the area where fabrics are manufactured. In addition to these, compressors, which provide compressed air to the weaving line, use energy. Two types of energy can be used in a specific weaving mill: electrical energy and thermal energy. Machines, air conditioning, lamps used for illumination and compressors consume electrical energy, while thermal energy is consumed by processes such as sizing and sometimes by air conditioning. Generally, thermal energy is obtained from coal, diesel oil, fuel oil, natural gas and steam, and the type of substance from which thermal energy is obtained is determined by the mill lay-out. The unit price of energy types and energy sources used for the manufacturing of woven fabric is given in ***Table 2*** for selected countries. The price of electrical energy changes between 0.045 – 0.100 $/kWh, the price being 0.084 $/kWh for Turkey. As seen from the table, unit energy prices are high for Turkey compared with the other countries, thus, to minimise the energy cost, the energy use of weaving mills must be analysed.

Table 2. *Unit cost of energy for woven fabrics (2006) [6].*

Cost factors	China	India	Turkey	Brazil	Korea	USA	Italy
Electrical Energy, $/kWh	0.080	0.095	**0.084**	0.050	0.060	0.045	0.100
Steam, $/kg yarn	0.070	0.071	**0.132**	0.110	0.070	0.041	0.160
Fuel-oil, $/kg	0.500	0.550	**0.430**	0.310	-	-	0.375
Gas, $/ft^3	-	-	**-**	-	0.500	0.090	-

Table 3. *Specific energy consumption of weaving preparation processes.*

Process	Specific energy consumption [14]	Specific energy consumption [15]
Automatic Winding, kWh/kg	-	0.4
Clasical Winding, kWh/kg	-	0.1
Warping, kWh/kg	0.17	0.1
Sizing	0.05	0.03 kWh/kg (electrical energy)
	-	5 MJ/kg (thermal energy)

Table 4. *Specific energy consumption of different types weaving machines [14].*

Type of weaving machine	Specific enery consumption, kWh/kg
Ordinary weaving machine	1.9
Cimmco loom	1.9
Ruti-B loom	0.95
Ruti-B narrow loom	2.3
Ruti-B ide loom	3.2

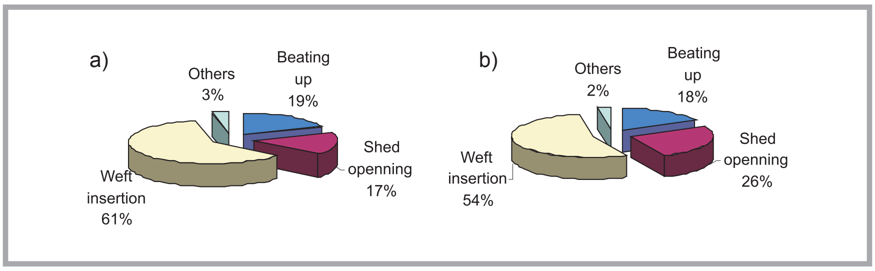

Figure 1. *Distribution of energy consumption among weaving functions [8]; a) with eight heald shafts b) with sixteen heald shafts.*

Energy consumption in weaving preparation

Energy is used for operating machines, air conditioning, illumination, compressors and the sizing process in weaving preparation. ***Table 3*** shows the specific energy (unit energy used for unit production) consumption of each weaving process. As shown, the energy consumption for winding changes between 0.1 and 0.4 kWh/kg, while it is 0.1 kWh/kg for the warping process. The level of energy consumption during weaving preparation changes according to the properties of the preparation machines, yarn and the fabric to be manufactured.

Energy consumption in the weaving part

Generally, electrical energy consumed by weaving machines changes between 1.7 - 4.2 kWh/kg. This value can be altered according to the design and weft pick per centimeter of the fabric to be produced, the properties of the yarn used as raw material and the properties of the machine used for manufacturing [8]. The specific energy consumption of different types of weaving machine is demonstrated in ***Table 4***.

A large part of energy used by weaving machines is consumed by such basic functions as shed opening, weft insertion and beating up, whereas a small amount of energy is needed for other functions. The distribution of energy use depending on the manufacturing function for the rapier weaving machine is illustrated in ***Figure 1***.

Energy analysis for chosen weaving mill

The weaving section of a textile mill containing bobbin dyeing, weaving and garment sections was chosen in order to conduct an energy analysis of its weaving preparation and weaving parts. This mill contains one warping machine, one sizing machine, one automatic drawing in machine, one sample sizing machine, one sample warping machine in the preparation part and 50 weaving machines, 32 of which are air jet and the others rapier. The number of machines and installed actual power data of the machines of the mill chosen can be seen in ***Table 5***. The total installed actual power of the chosen mill is 459.8 kW, 125.2 kW of which is used by all the weaving machines.

The distribution of installed actual power with respect to the equipment is shown in ***Figure 2***. It can be seen that machines comprise a share of 36.3% and compressors 29.4%, while the air conditioning units represent 27.10%.

The weaving mill chosen operates 3 shifts a day consisting of 8 hours and works 26 days a month. Considering the monthly operating time and number of machines, the monthly (April) energy consumption of the spinning mill chosen has been calculated, all the data of which are shown in ***Table 6***. The monthly total actual energy consumption of the weaving mill is 262368.2 kWh/month in March, as shown, 29.2% of which is consumed by weaving machines, followed by compressors (29.1%) (***Figure 3***).

The amount of fabric manufactured in a given month is 208847 m, and if the monthly energy consumption is divided by this, the specific energy consumption of the mill is obtained as 1.26 kWh/m for the month chosen.

In order to evaluate the annual energy consumption of the chosen mill, ***Table 7*** was constructed. The table also contains such production data as the monthly number of inserted wefts and the monthly fabric manufacture. The mill chosen uses coal to obtain thermal energy, the heating value of the coal being 5000 kcal/ton (20900 kJ/ton). The monthly fabric production of the mill changes between

Table 5. *Unit power consumption of chosen weaving mill.*

	Equipment type	Number of equipment	Installed actual power for unit machine, kw	Total installed actual power, kw
Weaving preparation machines	Sizing machine	1	20.6	20.6
	Indirect warping machine	1	2	2.0
	Direct warping machine	1	3.5	3.5
	Sample sizing machine	1	7.7	7.7
	Sample warping machine	1	1.6	1.6
	Automatic drawing in machine	1	6	6.0
Subtotal for weaving preparation machines			41.6	41.6
Weaving machines	Air jet weaving machines	32	2	64.0
	Rapier weaving machine	18	3.4	61.2
Subtotal for weaving machines		50	5.4	125.2
Other equipment	Compressors	134.8		
	Cleaning robots	17.6		
	Illumination	15.6		
	Air conditioning	125		
Subtotal for other equipment		293		
Total		459.8		

Table 6. *Monthly energy consumption of chosen weaving mill.*

Equipment type	Operating time, h/month	Hourly energy consumption, kWh	Monthly energy consumption, kWh/month
Sizing machine	593	20.6	12215.8
Indirect warping machine	384	2,2	844.8
Direct warping machine	110	3,5	385
Sample sizing machine	95	6	570
Sample warping machine	605	1.6	4758.6
Automatic drawing in machine	618	7.7	968
Subtotal for weaving preparation machines			19742.2
Air jet weaving machines	564	2	36096
Rapier weaving machine	615	3.4	37638
Subtotal for weaving machines			73734
Compressors	546	134.8	73600.8
Cleaning robots	582	17.6	10243.2
Air conditioning	562	125	70250
Illumination	618	15.6	9654
Loss,%2			5144
Subtotal for other equipment			168892
Total			**262368.2**

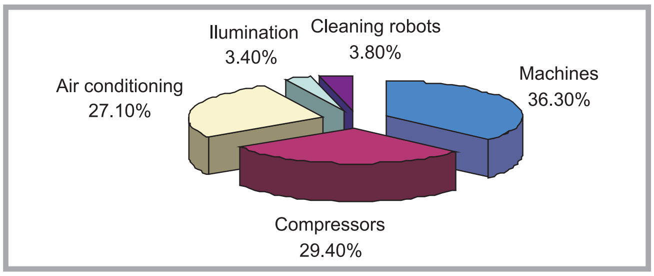

Figure 2. *Distribution of energy consumption in unit time for chosen weaving mill, %.*

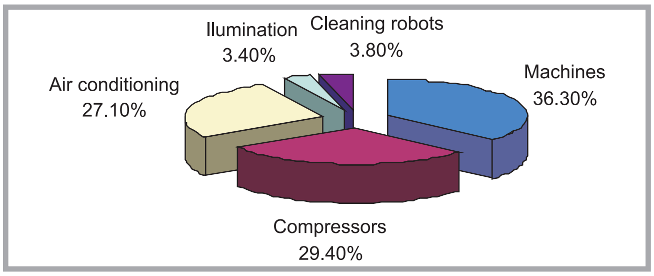

Figure 3. *Distribution of monthly energy consumption for chosen weaving mill, %.*

135249 - 261847 m, and the monthly electrical energy consumption is between 175350 - 265800 kWh/month.

The monthly energy consumption of the mill investigated has been divided by the monthly production quantity in order to determine the unit energy consumption of a unit length of fabric, which is known as the specific energy consumption. The variation obtained is shown in ***Figure 4***. Thermal energy consumption is calculated by considering the heat value of coal used in the mill. These are average values which change depending on the fabric properties.

Theoretical approach for specific energy consumption and application

Theoretical approach

A simple theoretical approach has been developed to obtain the total energy and specific energy needed for manufacturing any type of woven fabric. The energy consumption of the woven fabric considered is examined in detail below [3, 7, 9].

Calculation of energy consumption for machines

According to the approach attempted, a raw material should first be found for the fabric, and then the operating time of each machine must be obtained. Using the operating time and actual power of the manufacturing machines, the energy consumption of each machine during manufacturing can easily be calculated [3, 7, 9]. ***Table 8*** shows equations for calculation of the operating time for each machine according to the approach.

By using the operating time, the installed power, energy efficiency of each machine and the electrical energy used for each machine can be calculated. All the equations for determining electrical energy during processes are given in ***Table 9*** (see page 18). After calculation of the electrical energy needed for each step, all the data should be added to find the total electrical energy for the machines, E_M.

Calculation of energy consumption for other equipment

The energy used for air conditioning, illumination, compressors and cleaning robots can be taken as the energy for other equipment. The electrical energy used for illumination EE_{IL} in kWh and air conditioning EE_{AC} in kWh can be calculated in sequence, as given below.

$$EE_{IL} = E_{IL} \times \frac{s_1}{s_m} \quad (1)$$

$$EE_{AC} = E_{AC} \times \frac{s_1}{s_m} \quad (2)$$

Here, EE_{IL} and EE_{AC} are the monthly energy consumption for illumination and air conditioning, respectively, s_1 is the number of weft picks inserted for the manufacturing of the chosen woven fabric, and s_m is the number of monthly inserted weft picks for the mill. The electrical energy used by compressors and cleaning robots can also be calculated, which is similar to that for air conditioning and illumination. If an air jet weaving machine is used for manufacturing, the electrical energy needed for compressors EE_{Co} in kWh should be obtained from

$$EE_{Co} = t_W \times m \times E_{WCo} \quad (3)$$

where t_W is the operating time of weaving, m is the number of weaving machines used for manufacture, and E_{WCo}

Table 7. *Monthly energy consumption of chosen weaving mill.*

Months	Monthly fabric production, m/month	Monthly number of inserted wefts	Monthly electrical energy consumption, kWh/month	Monthly coal consumption, kg/month
January	135249.0	328612400	175350	20000
February	189503.5	451233700	219350	35000
March	261847.0	608681100	246850	44000
April	**208847.0**	**625866100**	**262368**	**20000**
May	198823.6	456662400	241450	37000
June	173057.0	432396600	235560	30000
July	189605.0	439084700	231500	30000
August	145661.0	331691200	215750	22000
September	207690.0	469211100	265800	40000
October	154692.5	379813100	202600	25000
November	187809.0	466395200	244000	30000
December	201573.0	452318800	260900	25000

Table 8. *Equations for calculation of the operating time for each machine.*

Process	Equation	Denotations
Warping	$t_{WA} = (\frac{L_{WA}}{V_{WA} \times \eta_{WA}} \times l_1)$	t_{WA} - Operating time of warping, min L_{WA} - Length of warp, m V_{WA} - Production rate of warping machine, m/min η_{WA} - Production efficiency of warping machine, % l_1 - Number of warp beams
Sizing	$t_S = (\frac{L_{WA}}{V_S \times \eta_S})$	t_S - Operating time of sizing, min V_S - Production rate of sizing machine, m/min η_S - Production efficiency of sizing machine, %
Drawing in	$t_D = (\frac{l_2 \times S_{WA} \times W}{V_D \times \eta_D})$	t_D - Operating time for drawing in machine, min V_D - Production rate of drawing in machine, pick/min l_2 - Number of weaving beams W - Width of woven fabric, cm S_{WA} - Warp pick per cm, tel/cm η_D - Production efficiency of drawing in machine, %
Weaving	$t_W = \frac{L \times S_{WE}}{60 \times n_W \times \eta_W \times m}$	t_W - Operating time of weaving machine, hour n_W - Production rate of weaving machine, pick/min L - Length of woven fabric, cm η_W - Production efficiency of drawing in machine, % m - Number of weaving machines S_{WE} - Weft pick per cm, pick/cm

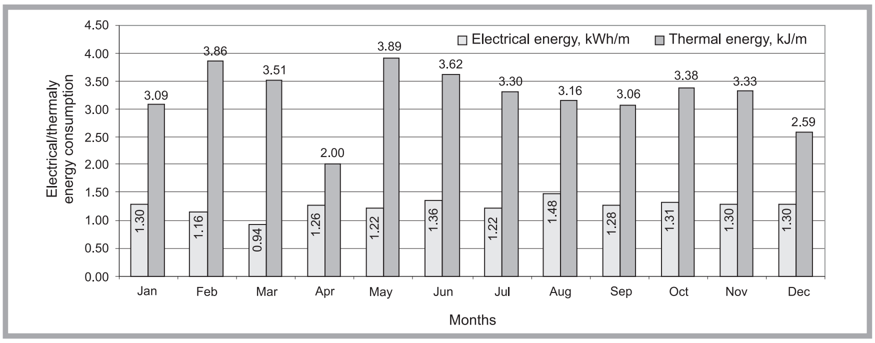

Figure 4. *Monthly specific energy consumption of chosen mill.*

Table 9. Equations for calculation of the energy consumption for each machine

Process	Equation	Denotations
Warping	$EE_{WA} = t_{WA} \times E_{WA} \times \eta_{EWA}$	EE_{WA} - Electrical energy used for warping, kWh t_{WA} - Operating time of warping, hour E_{WA} - Installed power for warping machine, kW η_{EWA} - Energy efficiency of warping machine, %
Sizing	$EE_S = t_S \times E_S \times \eta_{ES}$	EE_S - Electrical energy used for sizing, kWh t_S - Operating time for sizing, hour E_S - Installed power for sizing machine, kW η_{ES} - Energy efficiency of sizing machine, %
Drawing in	$EE_D = t_D \times E_D \times \eta_{ED}$	EE_D - Electrical energy used for drawing in, kWh t_D - Operating time for drawing in, hour E_D - Installed power for drawing in machine, kW η_{ED} - Energy efficiency of drawing in machine,%
Weaving	$EE_W = t_W \times E_W \times \eta_{EW} \times m$	EE_W - Electrical energy used for weaving, kWh t_W - Operating time of weaving, hour E_W - Installed power for weaving machine, kW η_{EW} - Energy efficiency of weaving machine,% m - Number of weaving machines
Total	$EE_M = EE_{WA} + EE_S + EE_D + EE_W$	EE_M - Electrical energy used for operating machines, kWh

Table 11. Technical data for machines used in the application.

Process	Number of machines	Production rate	Production efficiency, %	Installed power, kW	Actual power, kW
Warping machine	1	1000, m/min	90	25	20.6
Sizing machine	1	70, m/min	90	10	3.5
Automatic drawing in machine	1	150, pick/min	90	10	6
Air jet weaving machine	6	500, weft/min	85	8	2

Table 12. Energy consumption of machines.

Machines	Operatin time, min.	Electrical energy used by machines, kWh	Specific energy used by machines, kWh/kg
Warping machine	493.3	28.700	0.0030
Sizing machine	881.0	302.500	0.0320
Automatic drawing in machine	348.4	34.900	0.0037
Air jet weaving machine	915 hour	10980.000	1.1500
Total for machines		11346.100	1.1950
Compressors	915 hour	15372.000	-
Total		27718.100	-

is the actual power needed to use compressed air from compressors in the weaving machine.

Calculation of thermal energy consumption for sizing

Thermal energy consumption for the sizing process of a selected woven fabric, E_T, is found as follows:

$$E_T = K_T * A * \frac{s_1}{s_m} \quad (4)$$

Here, K_T in ton/month is the monthly amount of material used for obtaining thermal energy; and A in kcal/ton can be considered the heat value of the material used for obtaining thermal energy [3, 7, 9].

Total energy consumption

Consequently, the electrical energy used for process machines and other equipment should be summed to determine the total electrical energy used for manufacturing the woven fabric chosen. Furthermore, thermal energy should be calculated besides electrical energy. The specific energy can easily be calculated by dividing each energy type by the amount of fabric. Specific energy can be expressed in kWh/kg, kJ/kg by expressing the fabric amount in kilograms, kWh/m, and kJ/m by expressing the fabric amount in meters, respectively.

Application for chosen woven fabric type

The energy consumption of the woven fabric under investigation has been calculated by applying the procedure given above. ***Table 10*** shows properties of the chosen woven fabric. These properties of the fabric are similar to those of woven fabric, whose cost factors are given in ***Table 1***. This will make comparing the values obtained with the data in ***Table 1*** easier.

Technical data for the machines used for manufacturing the chosen fabric are shown in ***Table 11***. As can be seen, 6 air jet weaving machines, one for each weaving preparation machine, operated in the production line.

Electrical energy consumption of machines

Considering the data given in ***Table 10*** and ***Table 11***, the operating time for each process has first been determined using the equations recommended. Since it is difficult to explain the calculation of every process, the operating time for the warping step has been explained in detail. The length of the warp was determined as 55500 using warp shrinkage 10% and waste 500 m (***Table 10***). The operating time of the warping step (t_{WA}) is calculated below taking the production rate (V_{WA}) as 1000 m/min, the production efficiency (η_{WA}) as 0.90, and the quantity of warp beams as 8 for the warping machine,

$$t_{AW} = \frac{55500}{1000 \times 0.90} \times 8 = 493.3 \text{ min.}$$

Similarly, the operating time for each step has been calculated and then the electrical energy needed for machines determined using the equations given in ***Table 9***. Since air jet weaving machines were used for manufacturing, the energy consumption of compressors should be determined using equation (3). Actual power taken from compressors for compressed air has been established from mill records (E_{WCo}) as 2.8 kW, this value being used for calculation. All data obtained are given in ***Table 12***.

Table 10. Properties of chosen woven fabric.

Properties of chosen woven fabric	Data
Fabric width (W), cm	168
Weft pick per cm (S_{WE}), pick/cm	28
Warp pick per cm (S_{WA}), pick/cm	28
Weft shrinkage (B_{WE}),%	5
Warp shrinkage (B_{WA}),%	10
Weigh per square meter, g/m^2	112.96
Weft fineness (N_{WE}), Ne	30
Warp fineness (N_{WA}), Ne	30
Length of fabric (L), m	50000
Waste, m	500
Number of warp beams, I_1	8
Number of weaving beams, I_2	10

Electrical energy consumption of other equipment

So as to calculate the total electrical energy usage for the chosen fabric, the energy consumption of other equipment, such as air conditioning, illuminating and cleaning robots should be found. For this reason, data such as the monthly energy consumption for air conditioning, the illumination system, cleaning robots and the amount of monthly weft insertion should be obtained. The monthly energy consumption for air conditioning illumination, and cleaning robots is given in ***Table 13***. Furthermore, it has been determined from mill records that the total weft insertion is 625866100 picks/month for the month examined (April), and the number of weft insertions has been calculated as 140000000 picks. By applying the approach developed, the electrical energy consumption of other sections has also been found, the results of which are illustrated in ***Table 13***.

Thermal energy consumption for the sizing process

As explained before, thermal energy is needed for the sizing process, and the mill selected uses coal with a heat value (*A*) of 5000 kcal/ton with a price of 0.21 TL/kg. It has been determined from the mill lay-out that coal consumption for the month concerned is 20 tonnes. The thermal energy consumption for the chosen fabric has been calculated, using equation (5), as 9350.24 kJ.

Total energy consumption

The total energy needed for manufacturing the chosen fabric has been calculated by summing the electrical energy used for machines (11346.1 kWh), compressors (15372 kWh) and other equipment (21315 kWh), which came to 48033 kWh. Moreover, the thermal energy was found to be 9350.24 kJ. The specific energy for the chosen fabric can be obtained by dividing these data by the amount of fabric woven. The fabric amount can be considered in meters or kilograms, and the specific energy can be expressed in kWh/kg - kJ/kg or kWh/m - kJ/m. The weight of fabric has been calculated as 9488 kg, and these data have been used in the calculation of specific energy consumption. Besides this, in some literature, the energy cost is given, and the cost of specific energy should be calculated for comparison. All the data, including specific energy, have been calculated taking the price of electrical energy as 0.084$/kWh (as given in ***Table 2*** for Turkey), as given in ***Table 14***.

Table 13. *Electrical energy consumption for other equipment during the production of the chosen fabric.*

Other equipment	Monthly consumption, kWh/month	Share of selected woven fabric, kWh
Cleaning robots	10243	2291.3
Air conditioning	70250	15714.2
Illumination	9654	2159
Loss, 2%	5144	1150.7
Total for other equipment	**95291**	**21315**

Table 14. *Calculation of specific energy consumption and cost for chosen woven fabric.*

	Specific energy consumption according to weight	Energy cost, $/kg	Specific energy consumption according to length	Energy cost, $/m
Total electrical energy 48033 kWh	48033 / 9488 =**5.06 kWh/kg**	0.425	48033 / 50000 = **0.960 kWh/m**	0.080
Total thermal energy 9350.24 kJ	9350.24 / 9488 = **9.85 kJ/kg**	0.074	9350.24 / 50000 = **0.18 kJ/m**	0.014
Total cost		**0.499**	**Total cost**	**0.094**

Result and discussion

As a result of detailed investigations performed on the energy consumption of woven fabric, the following conclusions can be made.

It has been shown that weaving machines consume 29.2% of the total monthly energy consumption (262368.2 kWh/month), while compressors comprise 29.1% of the total energy consumption in the spinning mill chosen. Additionally, the specific electrical energy consumed for each month over a one year period has been calculated, and it has been determined that the values calculated change between 0.94 kWh/m and 1.48 kWh/kg.

The weaving mill under investigation uses coal for obtaining thermal energy, and the coal consumption of the mill changes between 20 - 44 tons over a one year period. The specific thermal energy consumed for each month has been determined, and it has been found that the values calculated change between 2 - 3.89 kJ/m.

With the simple theoretical model developed, the total electrical energy consumed during the manufacturing of 100% cotton woven fabric produced with both 20 tex warp and weft yarn with a weight of 112.96 g/m^2 in the spinning mill chosen has been calculated as 48033 kWh. The thermal energy used for this fabric has been found to be 9350.24 kJ.

The specific energy consumption of the chosen fabric has been calculated as 5.06 kWh/kg for electrical energy and 9.85 kJ/kg for thermal energy. The values calculated have been compared with data available in literature (2.1 - 5.6 kWh/kg, 8.3 - 17 kJ/kg and 5.7 - 5.8 kWh/kg, 2.2 - 25 kJ/kg) [12, 14].

The specific energy cost of the chosen fabric has been calculated as 0.094$/m using the same unit prices as in the literature compared. The data for specific energy cost given in literature change between 0.057 - 0.119 $/m, the data for Turkey being 0.082 $/m.

It has been shown that there is good agreement between the data calculated and those given in literature. The small differences have been attributed to differences in the waste amount, resulting from warp shrinkage, yarn waste, and operation parameters such as the type, mechanical efficiency, energy loss and waste ratio of machines.

It has been demonstrated that the approach given in this study can be used to calculate the total and specific energy consumption of a particular fabric type with reasonable confidence.

References

1. *Ormerod A., Sondhelm W. S.; Weaving Technology and Operations, The Textile Institute, 1995.*
2. *Başer G.; Weaving Technic and Art, TMMOB Chamber of Textile Engineers Press, Volume1, No: 2, İzmir, 1998 (in Turkish).*
3. *Kaplan E.; The Cost Factor in Textile Industry and General Utilization of Energy Cost, MsC Thesis, Cukurova University, Institute of Natural and Applied Science,*

Textile Engineering Department, Adana 2004 (in Turkish).
4. Ak M.; Cost Constitution and Accounting Organisation in Textile Mills, M.Sc. Thesis, University of Marmara, Institute of Social Science, 117 pp., İstanbul, 2000 (in Turkish).
5. Haşıl Ç.; Application of Cost Accounting in Textile Industry, M.Sc. Thesis, University of Istanbul,, Institute of Social Science, 115pp., İstanbul,1999 (in Turkish).
6. ITMF, International Comparison of Manufacturing Costs, Spinning/Weaving/ Knitting, Sweden: International Textile Manufacturers Federation; 2006.
7. Kaplan E., Koç E.; Cost Calculation in Textile Mills-Woven Fabric Cost, Cukurova University Journal of Faculty of Engineering and Architect, No 21, 1-2, pp. 45-61, June/December 2006 (in Turkish).
8. Özgan Ş. S.; The Investigation of Factors Affecting Production Cost of Woven Fabrics, MsC Thesis, University of Uludağ, Institute of Natural and Applied Science, Bursa, 1995 (in Turkish).
9. Bilge F. A.; The Development of System Designed by Using Production Cost Factors of Woven Fabric, M.Sc. Thesis, Istanbul Technical University, Institute of Natural and Applied Science, İstanbul, 110pp., 2000 (in Turkish).
10. Kuşçuoğlu R.; Analysis of Turkish Textile And Clothing Sectors, MsC Thesis, Cukurova University, Institute of Natural and Applied Science, Textile Engineering Department, Adana, 2002 (in Turkish).
11. EMS-Textile Project: Promotion of Energy Management Practices in the Textile Industries of Greece, Portugal, Spain and Bulgaria, Intelligent energy Europe, Benchmarking Information V.4, March 2006, www.ems-textile.net/files/Benchmarking%20 Information_v.5.doc
12. Visvanathan C., Kumar S., Han S.; Cleaner Production in Textile Sector: asian Scenario, National workshop on "Sustainable Industrial Development through Cleaner Production", Srilanka, 2000, http://www.serd.ait.ac.th/smi2/SMI/roadmap/Presentations/CP_Textile_Asia.pdf.
13. Tarakçıoğlu I.; Energy Consumption and Conservation of Textile Finishing Mills, Bursa:Uludag University Press; 1984. (in Turkish).
14. Energy Use Profiles For Key Industry Sectors, www.uneptie.org/energy/act/cp-ee/docs/chapter5.pdf
15. Şenol F.; Energy Consumption and Conservation in Weaving Preparation Mill, Seminar Notes about Energy Consumption and Conservation in Textile Mills, Bursa: Sümerbank Textile Education and Research Institute, 1985; Number 77 (in Turkish).
16. Alpay H. R.; Energy Consumption and Conservation in Weaving Machines, Seminar Notes about Energy Consumption and Conservation in Textile Mills, Bursa: Sümerbank Textile Education and Research Institute, 1985; Number 77 (in Turkish).

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Department of Clothing Technology and Textronics

As a result of restructuring the Faculty of Material Engineering and Textile Design, Technical University of Lodz, the **Department of Automation of Textile Processes** and the **Department of Clothing Technology** integrated and formed a new organisation unit, called

the **Department of Clothing Technology and Textronics**

(designated as K-414 in the University organisation system). The scientific activity of the new department will cover the following fields (defined by the Ministry of Science and Higher Education):

- Textile science
- Material engineering
- Automation and robotics
- Electronics

The staff of the new department have experience in the following fields, which are the basis of their future activity:

- Clothing technology and material science
- Textronics and textronic systems
- Technology and organisation of production processes of ready made textiles
- Ready made textile products of new generations
- Identification and optimisation of machines and equipment used in manufacturing processes or ready-made textile products
- Properties of flat textile products
- Clothing comfort
- Fashion and design
- Automation of textile processes
- Electrical engineering and electronics in textile science and technology
- Technical metrology and instrumentation of measurement systems
- Methodology of experiments in scientific investigations

We kindly invite all who are interested in the fields of our activity to cooperate with us.

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