Investigation of Specific Energy Consumption and Possible Reduction Measures of Textile Spinning Mills

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Abstract: Energy plays an important role in the growth of any country in the world. Global energy crises, rapid growth rate, high production demand and increasing energy cost are the major factors for adopting energy conservation techniques. Pakistan energy crisis threatens the textile industry. This crisis reduces the entire textile production capacity by 30%. Keeping this scenario in view, a study and calculation, presented in this paper, has been conducted for the investigation of specific energy consumption (SEC) of 20tex and 30tex cotton yarn. The purpose of this work is not only to investigate the SEC but also employing better processing techniques to reduce SEC. The level of reduction in SEC depends on the amount of investment and the use of modern technology. This study results depicted 8 % energy consumption has been reduced in the spinning mills. It also helps to control the energy crisis of Pakistan.

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1. Introduction:

Energy plays an important role in industrial development and economic growth rate of a country. Global manufacturing industries consumption of 127 Exajoules (EJ) is almost 1/3 of the total energy consumption in 2007. Textile and leather industries were at the 8th order of energy consuming manufacturing industries [1]. Global energy crisis, rapid growth of industries, demand of high production capabilities and increasing fuel cost are responsible for finite availability of energy. These factors also compel the industrialists to adopt energy conservation plans [2, 3].

Pakistan is facing one of the worst energy crises. This is not only responsible for the decline in the economic growth rate but also shutting down of mains industries. This also threatens textile industry, which is one of the biggest industry of Pakistan [4, 5]. This industry contributes almost 66 % of the total exports and employs 38 % of total industrial labor. It also contributes 8.5 % of the GDP of this country [4, 6, and 7]. Spinning is one of the largest sectors of Pakistan, having 442 spinning mills. This crisis has reduced the entire textile sector production capacity by 30 % [4].

This alarming position for the entire textile industry becomes more worsen, when electricity prices increases and production capacity decreases. It is best time for industrialists to identify the energy wasting factors, implement energy conservation plans and others remedial measures to sustain their existence by reducing the cost of energy. Keeping this situation in mind, National Productivity Organization (NPO), Ministries of industries and Production and Govt. of Pakistan are offering Energy Efficiency Program for the entire industries in Pakistan. NPO has suggested that about 10% to 15 % energy can be saved in spinning [8].

There is also a great concern to save energy at the international level. Many studies have been carried out on energy conservation in the fields of textile and spinning [9, 10, 11 and 12]. Most important factors of energy conservation are high capacity utilization, fine tuning of equipments and technology up-gradation [2]. Motor is one of the important equipment in a spinning mill. Energy conservation in ring department motors are achieved by introducing the particle swarm optimization (PSO) controllers. This PSO controller maintains maximum efficiency of flux level in the motors and reduces the operating cost [13]. Many textile machines manufacturers has adopted energy efficient techniques in their latest machines. The use of modern inverter technology has also proved quite fruitful [14, 15, and 16].

2. Materials and Methods

2.1. Materials

Detail of Mills: Seven small capacity spinning mills containing 21120 spindles were selected for the present study in the South Punjab region of Pakistan. These machines imported from world's lead manufacturer (Rieter, Toyoda and Schalafhorst) and installed in the mills to provide the customers with state of the art yarn. The yarns spun in these mills are of high quality, which could be exported or consumed locally. The yarn was free from all defects and suitable for manufacturing of all sorts of cloths. These Mills operates continuously throughout the year through their gas power plants.

Detail of Spinning Processes: In the spinning process, textile fibers (either natural fibers such as cotton, silk, wool, jute or manmade fibers like viscose, polyester) are converted into the yarn. Spinning for staple fibers can be divided into three processes: pre spinning process, spinning process and post spinning process as shown in Figure 1 [17].

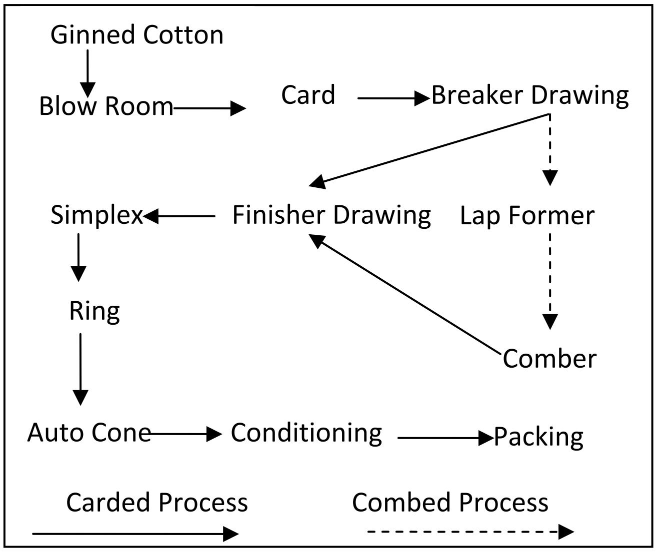

Figure 1. Flow of a conventional spinning process.

2.2. Methods

Experimental Design: This work strives and aims to identify/highlight factors that can help to save energy in the spinning mills. The methodology adopted for this purpose is as follows:

1. Collection of data regarding all energy consuming machines, production capacities and process parameters
2. Calculate Specific energy Consumption (SEC)
3. Employee better processing techniques to reduce specific energy consumption

On the basis of collected data of average energy consumption by spinning processes and supporting department's machines of a 21120 spindle spinning mills, analysis shows that Ring department consumed maximum energy (41.58 %); air condition is the next (second) largest unit as far as energy consumption was concerned (22.81 %). Card, Filter Plant, Blow Room and Compressor consumed 7.04 %, 4.88 %, 4.66 % and 4.01 % of the total energy consumption respectively. Energy consumed by spinning processes is 65.57% and supporting department's machines are 34.43%. Load distribution is shown in the Figure 2 and Figure 3.

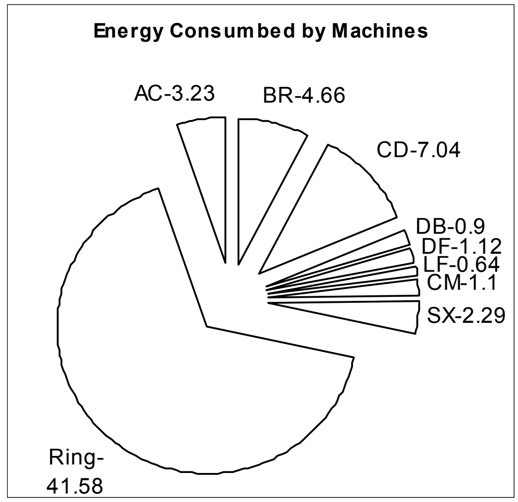

Figure 2. Energy Consumed by Spinning Processes

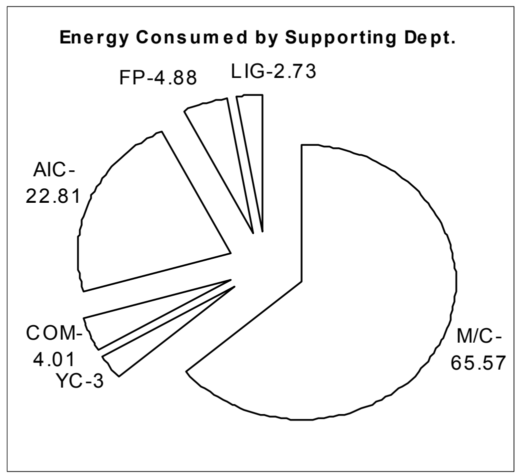

Figure 3. Energy Consumed by Supporting Dept.

Specific energy consumption (SEC) is defined as ratio of kWh of energy consumed to the unit weight of material processed by this energy consumption. It is represented by kilo watt hour per kilogram (kWh/kg) or electrical units per pound (kWh/lb). Specific energy consumption values are different in different countries and mills due to different production variables (delivery speed, twist level, spindle speeds and machines efficiencies) and different linear densities (count).

The value of Specific energy consumption is known to be high for fine yarn and low for the coarse yarn. The value of Specific energy consumption is also high for high level of twisted yarn (Warp Yarn) and low for low level of twisted Yarn (Hosiery Yarn) for the same yarn count. [10].

Table 1. Specific Energy Consumption of Spinning Mills

Dept.		20tex (30Ne) Combed				30tex (20Ne) Carded			
		Load (KW)	**hrs/day**	**kWh /day**	**Prod. (Kg)**	**Load (KW)**	**hrs/day**	**kWh/day**	**Prod. (Kg)**
Blow Room	Machines	64.00	22.00	1408	8935	64.00	22.00	1408	10185
	Filter	16.35	22.00	360		16.35	22.00	360	
	Air Cond.	22.00	24.00	528		22.00	24.00	528	
Carding	Machines	96.56	22.00	2124	8577	96.56	22.00	2124	9574
	Filter	31.00	22.00	682		31.00	22.00	682	
	Air Cond.	30.00	24.00	720		30.00	24.00	720	
Breaker	Machines	12.41	22.00	273	8537	12.41	22.00	273	9533
Finisher	Machines	15.43	22.00	339	8497	15.43	22.00	339	9494
Lap Former	Machines	17.76	22.00	391	8457				
Comber	Machines	30.30	22.00	667	7462				
	Filter	39.22	22.00	863					
Simplex	Machines	31.40	22.00	691	7432	31.40	22.00	691	9463
	Air Cond.	36.30	24.00	871		36.30	24.00	871	
Ring	Machines	650.00	22.56	14664	7358	499.00	22.56	11257	9393
	Air Cond. 1					171.47	24.00	4115	
	Air Cond. 2	172.00	24.00	4128					
Auto cone	Machines	43.23	22.00	951	7260	43.23	22.00	951	9300
	Air Cond.	53.00	24.00	1272		53.00	24.00	1272	
Compressor		55.00	24.00	1320		55.00	24.00	1320	
Lighting		37.50	24.00	900		37.50	24.00	900	
Conditioning		41.00	8.00	328		41.00	8.00	328	
		1494.46		**33480**	**7260**	**1256**		**28140**	**9300**
Specific Energy Consumption (kWh/kg)			**4.61**				**3.03**		
Specific Energy Consumption (kWh/lb)			**2.09**				**1.37**		

Table 1 shows the specific energy consumption for the spinning mills which were under consideration. Analysis of this table shows that Specific energy consumption for 20tex (30Ne) combed weaving yarn is 4.61 kWh/kg (2.09 kWh/lb) and for 30tex (20Ne) carded Weaving yarn is 2.99 kWh/kg (1.37 kWh/lb).

Specific energy consumption of 20tex combed yarn is 3.49 to 3.62 in different countries [1, 10]. It is found that specific energy consumption of 20tex combed yarn was remarkably higher than the specific energy consumption of different countries. SEC of 30tex carded yarn is also very high, when it is compared with SEC values mentioned in Table 2.

Table 2. SEC (kWh/kg) for different Yarn Count

Yarn Count		**SEC for different Yarn Counts**	
		Combed Yarn	**Carded Yarn**
Tex	**Ne**	Weaving	Weaving
37	16	1.63	1.62
33	18	1.88	1.86
30	**20**	**2.12**	**2.09**
25	24	2.60	2.55
20	**30**	**3.64**	**3.57**
17	35	4.62	4.53
15	39	5.25	5.12
12	49	6.91	6.72

These SEC values are calculated from Equation 1 [10].

$$ER = 106.7 \times F^{-1.482} \times Dr^{3.343} \times n^{0.917} \times \alpha_{text} 0.993 \ldots\ldots \ (1)$$

Here, ER= Specific Energy Consumption (kWh/kg)
F = Yarn Linear Density (tex)
Dr = Ring Cup Diameter (m)
n = Speed Spindle (1000 rpm)
αtext = tex Twist Factor

After realization of high specific energy consumption, a proposal to conduct seven energy saving techniques were selected for the implementation [12]. This study will also focus on potential of annual saving, Original Investment required for the implementation and expected payback period. The proposal consists of following list of experiments.

1. Replacement of Conventional Copper Electrical chokes with energy efficient electronic chokes for light.
2. Replacement of aluminum ring cup adopter with plastic adopter.
3. Control the Ring pneumafil suction fan motor drive with energy efficient drive control system (inverter).
4. Replacement of Gravity die casting blades with Pressure die casting blades of Ring supply fan
5. Replacement of larger wharve dia spindle with smaller wharve dia spindle.
6. Control hard waste suction fans motor drive with energy efficient drive control system
7. Replacement of Conventional electric heaters energy with Boiler Steam energy at Yarn Conditioning Machine.

3. Discussions of the Results

3.1. Replacement of Conventional Copper Electrical chokes with energy efficient electronic chokes for light.

Study of conventional electrical copper choke with energy efficient electronic choke is given in Table 3. The energy consumption difference with these two types of tube lights is 45%. There were 1940 tube lights installed in a mill, which has the potential to save 1491782 PKR per annum. Low pay back period, means, this proposal is quite suitable for implementation.

Table 3. Analysis of conventional copper choke with energy efficient electronic choke.

Descriptions	**Energy Saving Calculation**
Power consumed by conventional copper choke	40 W / choke
Power consumed by energy efficient copper choke	22 W / choke
Energy Saving	45 % per choke
Installed tubes in the mill	1940
Energy saving per choke	0.018 kW
Annual saving (PKR) = 1940x0.018 kW x 365x24 hr/day x 5 (units Price)	1529496 PKR
Investment required (PKR)	1940 * 700 = 1358000
Payback period	11 Months

3.2. Replacement of aluminum ring cup adopter with plastic adopter

Study of replacement of heavier aluminum adopter with a light weight hard plastic adopters is given in the Table 4. Adopters are fixed on the Ring Rail on ring machine. Ring Rail moves up and down to wind the spun yarn on the ring bobbin. When aluminum adopter is replaced with a light plastic adopter, it reduces the motor load and save the energy up to 2.77 %. Annual saving from this activity is 59808 PKR. Low Pay back period shows, this proposal may be feasible for implementation.

3.3. Control the Ring pneumafil suction fan motor drive with energy efficient drive control system

Study of using energy efficient drive control system instead of conventional drive system is given in the Table 5. The energy efficient drive control system varies the speed of pneumafil suction fan with respect to level of pneumafil in the pneumafil box. Ring pneumafil is collected manually or automatically after some interval of time. In case of empty pneumafil box, energy efficient drive control system reduces the suction of pneumafil box through the reduction in fan speed. This suction increases gradually by change in the level of pneumafil in the pneumafil box. This energy efficient control system saves the energy up to 38.6 %. Low pay back period reflects its feasibility of this proposal.

Table 4. Analysis of aluminum adopter with plastic adopter

Descriptions	Energy Saving Calculation
Weight of Aluminum adopter	53 gram
Weight of Aluminum adopter	33 gram
Diff in Weight at 1056 spindle Ring Frame	21 kg
Power consumed by Ring Motor using aluminum adopter	50.4 kW
Power consumed by Ring Motor using aluminum adopter	49 kW
Energy saving per Ring motor	1.4 kW (2.77 %)
Annual saving per m/c (PKR)= 1.4 x 365x24 hr/day x 5 (units Price)	61320 PKR
Price of Adopter	114 PKR
Investment required for one machine (PKR)	120384 PKR
Payback period	24 Months

Table 5. Analysis of energy efficient drive system with normal drive at ring

Descriptions	Energy Saving Calculation
Power Consumed by Normal Drive	6.9 kW
Energy Efficient Drive System	4.3 kW
Power saving	2.6 kW
Energy Saving %age	37.68 %
Annual saving per m/c (PKR) =	
2.6kW x 365x24 hr/day x 5 (units Price)	113880 PKR
Investment required for one machine	55000 PKR
Payback period	6 Months

3.4. Replacement of Gravity die casting blades with Pressure die casting blades of Ring supply fan

Study of replacement of Gravity die-casting blades with Pressure die-casting blades of Ring Supply fan of air conditioning plant is given in Table 6. It saves the energy up to 16.06 % [18]. Low Pay back period shows, this proposal is feasible for implementation.

Table 6. Analysis of gravity die casting with pressure die casting blades of ring supply fan

Descriptions	Energy Saving Calculation
Weight of Gravity die casting	35 kg
Weight of pressure die casting blades	15 kg
Power Consumed by Gravity die casting	13.7 kW
Power Consumed by pressure die casting blades	11.5 kW
Power saving	2.2 kW
Energy Saving %age	16.06 %
Annual saving per supply fan (PKR) = 2.2 kW x 365x24 hr/day x 5 (units Price)	96360 PKR
Investment required for one machine	45000
Payback period	6 Months

3.5. Replacement of larger wharve dia spindle with smaller wharve dia spindle

Results of the study of using smaller wharve dia with larger wharve dia are given in the Table 7. It is clear from the table that smaller wharve spindles (Which are also light weight) consumed less energy than the larger wharve dia spindle. It saves the electrical energy up to 7.1

7 %. It is practically impossible to implement this proposal due to very high Pay back period. This long pay back period means that industrialist should keep this factor in mind that while planning the erecting of new spinning mills they should select the smaller wharve diameter spindles. Small wharve diameter spindles with large size of tin pulley and less spindle weight will give maximum production with less energy consumption.

Table 7. Analysis of ring spindle wharve dia.

Descriptions	Energy Saving Calculation
Power Consumed by 20.2mm Wharve dia spindle	46 kW
Power Consumed by 18.5mm Wharve dia spindle	42.70 kW
Power saving	3.3 kW
Energy Saving %age	7.17 %
Annual saving per m/c (PKR) = 3.3 kW x 365x24 hr/day x 5 (units Price)	144540 PKR
Investment required for one machine	4000*1056 = 4224000 PKR
Payback period	350 Months

Table 8. Analysis of energy efficient drive system with normal drive at auto cone

Descriptions	Energy Saving Calculation
Power Consumed by Normal Drive System	9.6 kW
Power Consumed by Energy efficient Drive Control System	8.4 kW
Power saving	1.2 kW
Energy Saving %age	12.50 %
Annual saving per machine (PKR)	1.2 kW x 365x24 hr/day x 5 (units Price)
	52560 PKR
Investment required for one machine	68000 PKR
Payback period	16 Months

3.6. Control hard waste suction fans motor drive with energy efficient drive control system:

Results of study of replacement of energy efficient drive control system with conventional drive system for Hard Waste suction is given in the Table 8. The energy efficient drive control system varies the speed of hard waste fan with respect to level of hard waste. Hard Waste collected manually or automatically after some interval of time. This energy efficient control system saves the energy up to 12.50 %. Pay back period reflects the feasibility for implementation of this proposal.

3.7. Replacement of Electric heaters energy with hot flue gases from generators at Yarn Conditioning Machine:

Study of replacement of change in medium of energy at Yarn conditioning machine is given in Table 9. The medium of energy in the yarn conditioning machine was Electric heaters. During collection of data, it was observed that hot flue gases from power generation plant are exhausted in the air and their heat energy is not utilized. These exhaust gases have potential to generate steam from boiler. As a result through installation of new boiler, fuel cost of the boiler is zero because medium of heat is exhaust gases from power generation plant. This saves the energy up to 100 %. This low pay back period reflects the feasibility of the implementation of this proposal. In case of composite Unit, no need of installment of new boiler because boiler is also used in weaving for sizing department and in processing for contentious process.

Table 9. Analysis of electric heaters energy with boiler steam energy

Descriptions	Energy Saving Calculation
Power consumed by Electric Heaters at Conditioning machine	82.30 kW
Power consumed in case of Boiler Steam at Conditioning machine	0 kW
Power Saving (kW)	82.30 kW
Energy Saving %age (in case of Boiler Installation)	100 %
Annual saving per ma/c (PKR) = 82.30 kW x 365x 24 hr/day x 5 (units Price)	3604740PKR
Investment required for New Boiler installation	5300000 PKR
Running cost of Boiler from Generator exhaust Gases	0 PKR
Payback period	18 Months

Table 10. Summary of Results

List of Proposal	Energy Saving(kW)	Qtn	Energy Saving(kW)	Original Investment Required(PKR)	Annual Saving(PKR)	Pay Back Period(Month)
Copper choke vs. energy efficient choke	0.018	1940	34.92	1358000	1529496	11
Aluminum adopter with plastic adopter	1.4	20	28	2407680	1226400	24
Normal pneumafil suction drive with energy efficient drive at Ring	2.6	20	52	1100000	2277600	6
Gravity die casting blades with pressure die casting blades	2.2	8	17.6	360000	770880	6
Normal hard waste suction drive with energy efficient drive at Auto cone	1.2	1	1.2	68000	52560	16
Electric heaters with Boiler steam energy	82.3	1	82.30	5300000	3604740	18
	TOTAL		**216**	**10233680**	**7184076**	
Average Pay Back Period (Month)	17					
Total Energy Consumed (kW)	2745					
After Energy Consumed (kW) / Saving %age	2529 / 8					
Count	**20tex Combed Weaving**			**30tex Carded Weaving**		
Before Units Consumed/day	33480			28140		
After Units Consumed/day	31596			26279		
Production (kg)	7260			9300		
Before Specific Energy Consumed (kWh/kg)	4.61			3.03		
After Specific Energy Consumed (kWh/kg)	4.35			2.83		

The summary of results of implementation of this study is summarized in Table 10. Which shows the reduction in specific energy consumption for 20tex combed weaving and 30tex carded weaving yarn after the implementation of this proposal. Analysis shows that average pay back period of this proposal is only 17 months. Low pay back period reflects the feasibility of the implementation of this proposal.

4. Conclusion

Analysis revealed that potential of energy saving was almost same as identifies by National productivity Organization, Pakistan. NPO has suggested that about 10% to 15 % energy can be saved in the spinning mills. This study saves the energy up to 216 kWh (8%) in each spinning mill. This is not only enhancing the profit margin but will also reduce the specific energy consumption value.

The level of reduction in Specific Energy Consumption depends on the use of technology by the mills and amount of investment. Mills considered in this study were equipped with latest technology machines (Rieter, Toyoda and Schalafhorst). That's why; level of reduction in SEC or saving was 8%.

The level of saving can be increased by high level of investment as well. But due to long Pay Back period and financial constraints are the major hurdles. It is also anticipated that implementation of energy saving techniques on 12 spinning mills can saves the energy equal to run a small capacity spinning mills. This can be a turning point to control the energy crisis of Pakistan.

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