TEKSTİL VE MÜHENDİS

(Journal of Textiles and Engineer)

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Ring İplik Eğirmede Enerji Tasarrufu: Daha Hafif Masura Kullanımı

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Online Erişime Açıldığı Tarih (Available online):30 Eylül 2022 (30 September 2022)

Bu makaleye atıf yapmak için (To cite this article):

Erman COŞKUN, R. Tuğrul OĞULATA (2022): Energy Saving in Ring Spinning: Use of Lighter Tube, Tekstil ve Mühendis, 29: 127, 125- 132.

For online version of the article: https://doi.org/10.7216/1300759920222912702

TMMOB Tekstil Mühendisleri Odası
UCTEA Chamber of Textile Engineers
Tekstil ve Mühendis
Journal of Textiles and Engineer

Yıl (Year) : 2022/3
Cilt (Vol) : 29
Sayı (No) : 127

Araştırma Makalesi / Research Article

ENERGY SAVING IN RING SPINNING: USE OF LIGHTER TUBE

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Gönderilme Tarihi / Received: 15.02.2021
Kabul Tarihi / Accepted: 02.08.2022

ABSTRACT: Energy saving has a great importance in the textile industry as in every field. In this study, the energy savings achieved by using lighter tube in ring spinning machines were examined under spinning mill conditions. Light tube produced by using lower density composites and with thinner wall thickness provides significant energy saving. Another advantage is ability of winding more yarn on the same size tube thanks to thinner wall thickness. As a result of the comparative energy analysis over 1000 hours; Energy saving up to 33.5 MWh/year/machine was found possible with the use of lighter tubes. With the contribution of the advantage of being able to wind more yarn on the tube, the total savings can reach 1825 USD/machine/year.

***Key Words*:** Spinning, ring spinning machine, light tube, energy saving.

RİNG İPLİK EĞİRMEDE ENERJİ TASARRUFU: DAHA HAFİF MASURA KULLANIMI

ÖZ: Enerji tasarrufu, her alanda olduğu gibi tekstil sektöründe de büyük önem arz etmektedir. Bu çalışmada, ring iplik eğirme makinelerinde daha hafif masura kullanılarak elde edilen enerji tasarrufu iplik işletmesi şartlarında incelenmiştir. Daha ince et kalınlığına ve daha düşük yoğunluğa sahip kompozitlerin kullanımıyla elde edilen hafif masuralar, ciddi bir enerji tasarrufu sağlamaktadır. Bunun dışında daha ince et kalınlığı sayesinde aynı ölçülerdeki masura üzerine daha fazla iplik sarılabilmesi diğer bir avantajdır. 1000 saati aşkın yapılan kıyaslamalı enerji analizleri sonucunda; daha hafif masura kullanımıyla yıllık makine başı 33.5 MWh'e kadar enerji tasarrufunun mümkün olduğu görülmüştür. Masura üzerine daha fazla iplik sarılabilme olanağının avantajının getirdiği katkılarla birlikte toplam yıllık tasarruf, makine başı 1825 USD'ye ulaşmaktadır.

Anahtar Kelimeler: İplik eğirme, ring iplik eğirme makinesi, hafif masura, enerji tasarrufu.

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***DOI:** https://doi.org/10.7216/1300759920222912702 www.tekstilvemuhendis.org.tr*

1. INTRODUCTION

In the ring spinning, 55-60% of the cost is raw material, 12-13% is energy, 8-9% is waste, 6-8% is labour, 3-4% is spare parts and consumables, % 12-14 of them is investment cost [1]. Since raw material and waste prices are determined by the markets, the optimization is not possible on these cost items. Among the controllable and improvable factors, energy has the most important share which is around 40% [2]. In this context, more than one study has been conducted on energy consumption and saving in ring spinning. Some studies in the literature are as follows.

Hasanbeigi (2010) reported energy consumption and energy improvement in textile mills, primarily separates textile mills within itself and focuses on yarn, weaving, finishing, etc. details the energy consumption in the sections. Afterwards, information is given about how to make energy optimization in textile plants and extensive and in-depth information about which steps can be taken to save energy is presented. In particular, the use of spindle oils with special additives, the optimum level of spindle oil in the spindle bearing, the selection of the right ring and spindle belt, the use of energy-efficient motor, the choice of lighter types possible in the selection of tube and spindles, softer motors start up software energy savings to be achieved. In addition, it was reported that additional energy savings can be achieved by choosing the right motor and optimizing the running time of the traveling cleaners used in ring machines [3].

Koc and Kaplan (2007) revealed the energy consumption in ring yarn production and the percentage of costs. In addition to the raw material cost, which constitutes about half of the yarn production cost, the other cost items were examined, it was stated that the share of energy is 17%. It was emphasized that 61% of the total energy consumed in a ring spinning mill is consumed by machines and half of this is consumed by ring spinning machines. On the other hand, it was reported that most of the energy consumption in the ring spinning machine is spent on the spindle drive and it consumes 85% of the energy. The accuracy of these data was tried to be confirmed by making energy measurements in a selected spinning plant. The plant energy measurements made in where both open-end and ring spinning machines were located. It was revealed that the ring spinning machines alone consume a little more than half of the energy consumed by the total machines. Additionally, it was reported that the amount of energy consumed per unit kg of yarn increases when the yarn count gets finer. [4]

Khurshid, Asad, Khan, Chaudhry and Ammanullah (2012) investigated in their study, the energy consumption as well as how the energy consumption can be reduced in the ring spinning plant. First, the processes in the ring spinning plant and their energy consumptions at each stage were explained. Based on the measurements made; It was reported that the ring department consumes the most energy in the yarn plant with a rate of 41.58%, followed by the air conditioning system with 22.81%. It was also stated that 65.57% of the total energy is consumed by spinning processes and 34.43% is consumed by auxiliary equipment and machinery (e.g. compressor, fixed boiler, etc.). The energy consumption of each process for Ne 20 carded and Ne 30 combed yarn was demonstrated by measurements. As a result of the studies carried out; It was reported that the energy consumption required for the complete production of 1 kg of Ne 30 combed yarn is 4.61 kWh/kg, and 3.03 kWh/kg for Ne 20 carded yarn [5].

Magdi, Naglaa, and Abeer (2011) report that a computer program was developed that calculates the specific energy consumption in compact spinning with different spindle speed curves and considering all spinning variables. It was tried to prove the energy at the minimum spindle speed determined according to the yarn properties, the dimensions of the used cop and the spindle speed curve. It was also reported that the computer software determines at which spindle speed the least energy consumption is achieved [6].

Soliman (1963) was investigated the energy consumption of the ring spinning machines used in cotton and worsted spinning in the doctoral thesis. In the study, the energy consumption of the ring spinning machine was examined under the titles of main energy and auxiliary energy. The main energy refers to the energy consumed for the drive of the spindles. The auxiliary energy refers to the energy consumed by the drafting system and the machine drive heads [7].

In the ring spinning machine, 75-80% of the energy is consumed by the spindle motor. The energy consumption of the spindle motor is affected by many factors such as traveller weight, spindle speed, ring diameter, spindle drive type, tubes weight etc. In this framework, the effect of tube weight that is an important factor on energy consumption was investigated in this study.

In the ring spinning machines, the yarn is wound on the tube that is also called as yarn carrier. Tubes were made from many different materials, including paper, wooden etc. in the past, but now are mostly made of high-performance plastics and composite materials. There are two main reasons for using high-performance plastic materials and composites in tube production. The first reason is need for winding more yarn by reducing the thickness of the tube. The other is saving energy by reducing the tube weight.

Figure 1. Tube [8]

Increasing tube weight causes more load on the spindle. Higher load increases the amount of force that must be overcome to keep the spindles rotating and this is leading to higher energy consumption [2]. In this respect, tube manufacturers' intention is producing lighter tubes by thinning the wall thickness and using lower density materials. At the same time, the tube should be able to withstand against the forces that occur on it during the spinning process, in the doffing process and the winding process for years. This is only possible through special composite structures which are reinforced by carbon and glass fibre.

Hereby instead of tubes with the wall thickness of 2,6-3,0 mm and weight of 32-45 g, the tubes with 1,8 mm thickness and 22-29 g weight are able to be produced [9]. In fact, tubes with the wall thickness of 0,5 mm and weight of 8 g were produced from high strength 100% carbon fibre, started to be tested in the market and are expected to be widely used in the near future.

Figure 2. Carbon tubes [10]

The savings in energy consumption by use of lighter tubes is considerable. For instance, just thanks to the use of 28 g tubes instead of 30-35 g, 10.8 MWh / year average energy saving can be achieved per ring spinning machine [11].

The aim of this study is to clearly demonstrate the energy savings achieved through using of lighter tubes in practical running conditions and to draw the attention of ring spinning machine users to this important issue. Although some information on the subject is encountered in the literature, the reachable data are very superficial and mainly from the product brochures. Therefore, this study will also contribute to the literature.

2. MATERIAL AND METHOD

In this study, the energy saving achieved by using lighter was demonstrated. For this purpose, ten different energy measurements were conducted.

In energy analysis, five different tube types were used and compared. Tubes are numbered from 1 to 5 depends on their specifications. The details of tubes were given in table 1 and figure 3.

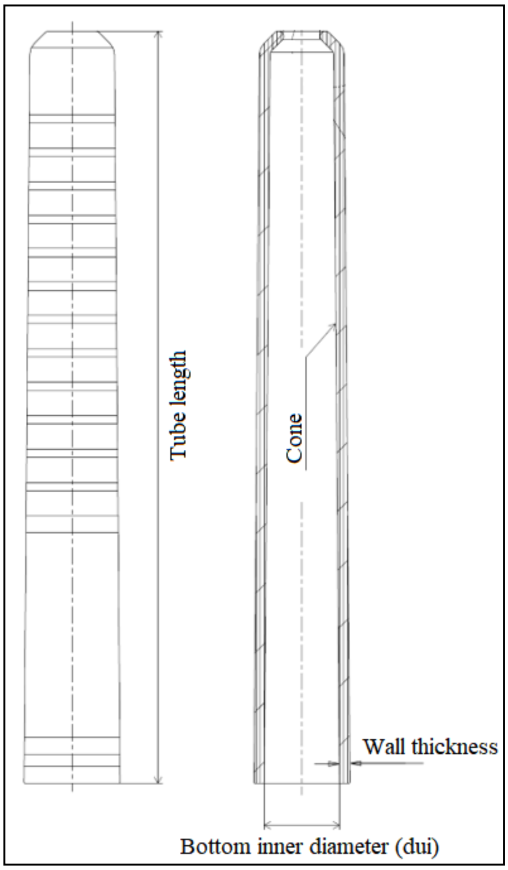

Figure 3. Tube dimensions [12]

Table 1. The details of tube types

Tube no	Tube weight (g)	Density (g/m^3)	Material	Wall thickness (mm)	Tube height (mm)	Bottom inner diameter (mm)	Cone (Conicity)
1	46	unknown	Poly-Butylene-Terephthalate	2.6	190	18	1:64
2	28	1.36	Polyamide	1.8	190	18	1:64
3	42	unknown	Poly-Butylene-Terephthalate	2.6	190	18	1:64
4	36	1.36	Polyamide	2.5	190	18	1:64
5	18.5	1.57	Unknown	1.1	190	18	1:64

The energy consumptions were measured, while ring spinning machines were in full production. It was investigated how the energy consumption required per 1 kg yarn production changed when the tube and cop`s weight changed only, and all other variables were kept constant in the ring spinning machine. The measured values were evaluated and compared in kilowatt-hour per kg yarn (kWh/kg). Energy analyser and integrated current transformers were used in the measurements. Details and figure of the devices are given below.

Three-phase energy analyser: Three-phase voltage and current values, active and reactive (capacitive or inductive) power values, active and reactive energy values, power factor, mains frequency, average and maximum powers, demand and harmonic distortions can be measured. It is a device that can record. Three-phase current transformers integrated in the ring spinning machine: Current transformers are measurement transformers used to measure the current passing through the circuit. Measuring high currents directly by measuring instruments is not only costly but also quite dangerous and difficult. Therefore, current transformers are also used to measure the current passing through the circuit. Long-term measurements are possible thanks to current transformers that continuously measure in the ring spinning machine. Energy consumption data can be obtained from the screen of the ring spinning machine or from mill monitoring systems connected to the ring spinning machines. More than 1 year of data can be obtained from facility monitoring systems and software [2].

The differences between these two measuring devices are basically as follows. While the energy analyser allows manual measurement, which is more difficult, it gives more detailed energy measurement data. On the other hand, current transformers allow easy and continuous measurement since they are integrated on the machine and energy measurement data can be taken directly on the machine screen. Although the energy measurement data is limited compared to the energy analyser, it is sufficient for the data needed in the study.

Ten separate energy measurements were carried out for four analyses conducted at three different facilities. In each analysis, energy measurements were made for two different tube weights under the exact same conditions and energy consumption changes were observed. Details of the machines, yarn properties, used energy measurement device in each analysis are given in table 2 below. Since current transformers were existed on the ring spinning machines which energy measurements II, III and IV were conducted, energy analyser was needed to use. But for energy measurement I, it was necessary to use external energy analyser due to absence of current transformers.

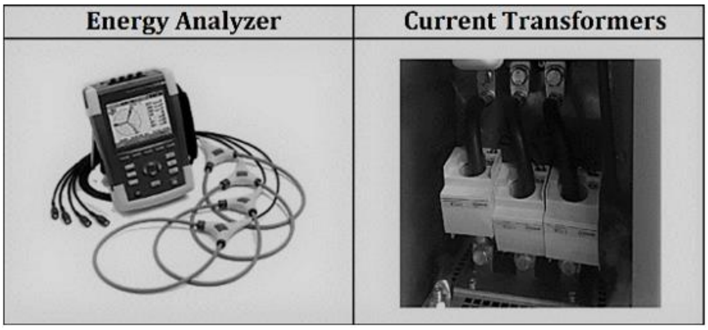

Figure 4. Energy Measuring Devices [2]

Table 2. The detail of energy analyzes

Analysis no	Energy measurement device type	Ring spinning machine parameters: Type	Ring diameter (mm)	Spindle quantity	Installed power of spindle motor (kW)	Eff. level of motor	Spindle speed (rpm)	Yarn details: Count (Ne)	Twist (T/m)	Material
I	EA	Cmpt	38	1824	80	IE3	23000	40	1020	Cotton
II	CT	Cmpt	38	1632	80	IE3	18500	30	755	Cotton
III	CT	Cnvt	38	1824	110	IE4	17000	28	770	Blends of PES/CV
IV	CT	Cnvt	38	1632	80	IE3	20500	30	776	Cotton

EA: Energy analyser, CT: Current transformers, Cmpt: Compact ring spinning machine, Cnvt: Conventional ring spinning machine

Eff. Level of Motor: The efficiency of an electric motor is defined as the ratio of usable shaft power to electric input power. IE4 > IE3

The spindle drive system of all ring spinning machines used in this study was same and four spindle drive system. All ring spinning machines had T Flange ring type and C type traveler shape was used during the measurements. As all energy comparisons for each analysis were done on same type of ring and same type of traveler i.e. same weight (same ISO number), same coating, same profile etc, no more details about ring and traveler was given,

3. RESULTS AND DISCUSSION

In order to see the effect of tube weight on energy consumption, multiple energy measurements were made in different spinning mills for this study.

As stated before; it is possible to produce lighter tubes with the same dimensions by thinning the wall thickness and using lower density composites. This allows winding more yarn in addition to energy saving. Since the priority in the spinning mills is winding more yarn on the tube (due to its higher efficiency, productivity advantages on ring spinning and winding machines), the energy consumption depends in more yarn on tube was also measured. The results of Analysis I conducted in Mill 1 was given in table 3. The figures were based 6-day average energy consumption.

Two different tubes were used for Analysis I; tube 1 and 2. The results given in the first and second rows of table 3 shows the energy saving by 4.8% occurs with the decrease in tube weight from 46 to 28 g. For this the amount of yarn wound on the tube was kept same for both tubes` types i.e. 54 g. Furthermore, the analysis was extended to check how the energy consumption changes when the amount of yarn on the tube is increased. The yarn amount was increased on tube 2 by 5.6% and 10.2% and results were compared with tube 1. The compared results of figures in the third row and first row of table 3 indicates 3.1% energy saving for tube 2, despite 5.6% more yarn on the tube 2. The compared results of figures in the in the fourth and first row shows 2.7% energy saving for tube 2, despite 10.2% more yarn on the tube 2.

The results of Analysis II conducted in Mill 2 was given table 4. The figures were based 6-day average energy consumption.

Two different tubes were used for Analysis II; tube 2 and 3. Although 19.2% more yarn (9 g) wound on the tube 2, 5 g. lighter cop weight could be reached thanks to 14 g. lighter tube weight than tube 3. Accordingly, 2.2% energy saving was observed.

Analysis III was conducted at mill 3 and energy measurements were made during full traveller lifetime (6 days). The results were given in table 5.

Table 3. Energy saving depends on tube weight – Analysis I

Tube no	Tube weight (g)	Yarn weight (g)	Yarn weight increase (%)	Cop weight (g)	Cop weight decrease (g)	Cop weight decrease (%)	Energy consumption (kwh/kg)	Energy saving (kwh/kg)	Energy saving (%)
1	46	54	-	100	-	0.00%	1.721	-	-
2	28	54	0.00%	82	18	18.00%	1.638	0.083	**4.80%**
2	28	57	5.60%	85	15	15.00%	1.668	0.053	**3.10%**
2	28	59.5	10.20%	87.5	12.5	12.50%	1.674	0.047	**2.70%**

Table 4. Energy saving depends on tube weight – Analysis II

Tube no	Tube weight (g)	Yarn weight (g)	Yarn weight increase (%)	Cops weight (g)	Cops weight decrease (g)	Cops weight decrease (%)	Energy consumption (kwh/kg)	Energy saving (kwh/kg)	Energy saving (%)
3	42	47	-	89	-	0.0%	1.209	-	-
2	28	56	19.1%	84	5	5.6%	1.182	0.027	**2.2%**

Table 5. Energy saving depends on tube weight – Analysis III

Tube no	Tube weight (g)	Yarn weight (g)	Yarn weight increase (%)	Cops weight (g)	Cops weight decrease (g)	Cops weight decrease (%)	Energy consumption (kwh/kg)	Energy saving (kwh/kg)	Energy saving (%)
4	36	56	-	92	-	0.0%	1.297	-	-
2	28	61	8.9%	89	3	3.3%	1.244	0.053	**4.1%**

The results given in the first and second rows of table 5 shows the energy saving by 4.1% achieved with the decrease in tube weight from 36 to 28 g Although 8.9% more yarn (5 g) wound on the tube 2, 3 g lighter cop weight could be reached thanks to 8 g lighter tube weight in comparison to tube 4. The result of Analysis III shows once more energy saving through lighter tube.

In all analyses described so far, there were reductions of 8, 14 and 18 g in tube weight. In Analysis IV, the effect of tube weight decrease of 23 g on energy consumption was measured during one cop filling time.

The results given in the first and second rows of table 6 shows the energy saving by 1.9% achieved with the decrease in tube weight from 42 to 18.5 g. Although 21.6% more yarn (11 g) wound on the tube 5, 12.5 g lighter cop weight could be reached thanks to 23.5 g lighter tube weight in comparison to tube 3. The results in table 6 show two main advantages of lighter tube; possibility of more yarn on the tube as well as energy saving.

The obtained results were also investigated via the statistics of regression analysis that is given in table 7.

According to the obtained data as a result of the regression analysis, we can conclude with the following formula how many percentages energy saving can be achieved by the percentage reduction in cops weight. It would be correct to use this data for applications in the production of yarn count between Ne 28 - Ne 40 and for 190 mm tube height.

$$ES = (0.194 \times CWd) + 0.006$$

(1)

ES: Energy saving in percentage

CWd: Cops weight decrease in percentage

$$CWd = \left[1 - \left(\frac{TW_1+YW_1}{TW_2+YW_2}\right)\right]/100$$

(2)

TW_1: Weight of lighter tube in gram

TW_2: Weight of heavier tube in gram

YW_1: The amount of yarn on the lighter tube in gram
YW_2: The amount of yarn on the heavier tube in gram

When the data in table 3,4,5,6 was examined; It was observed that energy savings between 1.9 and 4.8% was achieved thanks to the lighter tube. The average energy saving of all analyses was 0.0289 kWh/kg. The annual energy saving is 11.6 MWh for the machine which makes 1150 kg/day production and runs annually 350 days. Considering that the energy cost of 1 kWh is 0.086 USD [13] the annual savings are calculated as 1000 USD/ machine.

In addition to energy saving achieved by lighter tube, there are also additional advantages thanks to ability of winding more yarn on the tube. These advantages are as follow.

Table 6. Energy saving depends on tube weight – Analysis IV

Tube no	Tube weight (g)	Yarn weight (g)	Yarn weight increase (%)	Cops weight (g)	Cops weight decrease (g)	Cops weight decrease (%)	Energy consumption (kwh/kg)	Energy saving (kwh/kg)	Energy saving (%)
3	42	51	-	93	-	-	1.365	-	-
5	18.5	62	21.6%	80.5	12.5	13.4%	1.339	0.026	**1.9%**

Table 7. Regression analysis

Regression Statistics	
Multiple R	0.766112917
R Square	0.586929001
Adjusted R Square	0.535295126
Standard Error	0.012436361
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.00175808	0.00175808	11.36713064	0.00976360
Residual	8	0.00123730	0.00015466		
Total	9	0.00299538			

	Coefficient	*Standard Error*	*t Stat*	*P-value*	*Lower %95*	*Upper %95*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.00571510	0.00553730	1.03210824	0.33221141	-0.00705395	0.01848414	-0.00705395	0.01848414
X Variable 1	0.19378764	0.05747787	3.37151756	0.00976360	0.06124344	0.32633183	0.06124344	0.32633183

1) Efficiency and productivity increase for ring spinning machine thanks to less doffing,
2) Efficiency increase for winding machine thanks to more yarn amount on tube,
3) Less splice points on cones, means better yarn quality.
4) Saving from yarn waste,
5) Lower compressed air consumption thanks to less splice, means energy saving.

These advantages were also investigated during Analysis V and the results were given in table 8.

The following advantages are calculated according to figures of table 8.

- 3.1 kg/day additional production. When 0.5 USD/kg margin is considered for Ne 30/1, compact combed cotton yarn, the additional profit per year will be 540 USD/machine/year.
- 3951 fewer cops will be needed. This means 3951 fewer splices. By considering that 3.4 meters of yarn waste is generated in each splice, it is calculated that 0.26 kg/day less yarn waste will occur for Ne 30/1 yarn. The price difference in between yarn and yarn waste is approx.3 USD/kg. So, the additional profit per year will be 270 USD/machine/year.
- The compressed air consumption per splice is 4.5 litres and the cost per cubic feet of air is 0.000208 USD [14]. So, thanks to 3951 fewer splices per day, the additional profit per year will be 45 USD/machine/year.

So, the total additional savings are calculated as 825 USD/machine/year. When this figure is combined with the figure of energy saving on ring spinning machine, total savings are reached to 1825 USD/machine/year.

4. CONCLUSION

In this study, ten energy measurements were conducted in four different analyses and in three different facilities to exhibit the energy saving provided using light tube. In total, over 1000 hours of energy measurements were carried out. All the obtained data of the analysis were compared, and the energy savings achieved by the light tube were revealed for the each one. In addition to the energy saving in the ring spinning machine, the production increase in the ring spinning machine and the reduction in the number of splices in the winding machine and accordingly the saving in compressed air consumption were revealed clearly. All these results were summarized as follows.

Thanks to use of lighter and thinner tubes;

- Energy saving in between 1.9 – 4.8% is possible.
- Energy saving in between 0.026 – 0.083 kWh/kg is possible i.e., 10.5 – 33.5 MWh energy saving per year per machine.
- 0.3% higher production is possible. It means over 1000 kg additional production per year.
- Around 1.4 million splices per year are possible. It makes 6.3 million litres less compressed air requirement.
- The saving of 1825 USD/machine/year is possible (machine with 1824 spindles).

The unit price of tube no 1, 3, 4 is around 0.5 USD, tube 2 is around 0.9 USD and tube 5 is around 1.6 USD. When the largest price gap (1.1 USD) is considered and the needed tube quantity is calculated for ring spinning machine with 1824 spindles (1824 x 2.5 tubes needed per spindle for ring spinning machine link connected to winder), the additional investment cost for lighter tube is calculated as 5016 USD (1824 x 2.5 x 1.1 USD). Thanks to the lighter tube`s saving of 1825 USD/machine/year, the additional investment cost is paid off in 33 months and the saving in the following years will be obvious.

In this context, the replacement of the tubes with the lighter ones is recommended in case of obtaining a guarantee of performance and lifetime from the tube suppliers for at least 5-6 years. It will also be right step to have lighter tubes within the technical possibilities for new spinning mill investments. However, the unbalanced running tube has great importance to not create performance loss, spindle problems and not energy increase instead of saving.

Table 8. Additional savings thanks to ability of winding more yarn on the tube – Analysis IV

Tube no	Tube weight (g)	Yarn weight (g)	Cops filling time (min)	Doffing per day	Doffing time (min)	Non-production time (min)	Eff. saving (%)	Daily production (kg)	Needed cops for daily production	Saving in yarn waste (kg)
3	42	51	104	10.96	2	21.9		1150.0	22549	
5	18.5	62	126	9.05	2	18.1	0.3%	1153.1	18598	0.26
Savings						**3.8**	**0.3%**	**3.1**	**3951**	**0.26**

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