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Energy Saving in Ring Spinning: Thanks to Lower Technological Suction Amount

Ring İplik Eğirmede Enerji Tasarrufu: Daha Düşük Teknolojik Emiş Miktarı Sayesinde

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Abstract

Energy need is increasing day by day in the world and this increase causes more carbon emissions and global warming. In this regard, energy saving is essential in every industry.

In this study, a special energy saving in the ring spinning was studied in the textile industry, which has an important place in the world energy consumption. Technological suction amount's effect to energy consumption, which is one of most important energy consumption affecting factors on ring spinning machines, was investigated. Firstly, technological suction was described where and how it is used for conventional and compact ring spinning machine. Thereafter the results obtained by performing energy measurements on different ring spinning machines were given to see how the amount of technological suction affects energy consumption in practice.

As a result of study, it was observed that thanks to each Hz decrease in the frequency of the fan motor, the saving in total energy consumption per 1 kg yarn is around 1% when the machine in full production. When we evaluate this result for a spinning mill with 20 ring spinning machines with 1632 spindles; it was seen that annual energy savings of 315 - 350 MW per mill can be achieved thanks to lower of the suction amount.

In this context, it was proven in the study that significant energy savings can be achieved by decreasing the amount of technological suction, especially in spinning mills with conventional and compact ring machines with inverter-controlled fans.

Keywords: *Ring spinning machine, energy consumption, technological suction*

Öz

Dünyada enerji ihtiyacı her geçen gün artmakta ve bu artış daha fazla karbon salınımına ve küresel ısınmaya neden olmaktadır. Bu bağlamda, enerji tasarrufu her sektörde önemlidir.

Bu çalışmada, dünya enerji tüketiminde önemli bir yere sahip olan tekstil endüstrisinin bir kolu olan ring iplikçiliğinde özel bir enerji tasarrufu çalışmasına yer verilmiştir. Ring iplik makinelerinde, enerji tüketimini etkileyen en önemli faktörlerden biri olan teknolojik emiş miktarının etkisi araştırılmıştır.

İlk olarak, teknolojik emişin konvansiyonel ve kompakt ring iplik makinelerinde nerede ve nasıl kullanıldığı anlatılmıştır. Daha sonra teknolojik emiş miktarının pratikte enerji tüketimini nasıl etkilediğini görmek için farklı ring iplik makinelerinde enerji ölçümleri yapılmış ve elde edilen sonuçlar çalışma kapsamında verilmiştir.

Çalışma sonucunda; makine tam üretimde iken, fan motorunun frekansındaki her bir Hz'lik düşüş sayesinde, 1 kg iplik için gerekli toplam enerji tüketiminde, % 1 civarında tasarruf oluştuğu gözlemlenmiştir. Bu sonucu 1632 iğli 20 ring iplik makinesine sahip bir iplik işletmesi için değerlendirdiğimizde; emiş miktarının düşürülmesi sayesinde tesis başına yıllık 315 - 350 MW enerji tasarrufu sağlanabileceği görülmüştür.

Bu bağlamda, özellikle invertör kontrollü fanlara sahip konvansiyonel ve kompakt ring makinelerinin bulunduğu iplikhanelerde, teknolojik emiş miktarının düşürülerek önemli enerji tasarrufu sağlanabileceği çalışmada kanıtlanmıştır.

Anahtar Kelimeler: *Ring iplik eğirme makinesi, enerji tüketimi, teknolojik emiş*

1. Introduction

Technological suction is mainly used for only fiber waste suction in conventional ring spinning machines, whereas it is used for both fiber waste and compacting suction for compact ring spinning machines.

In both conventional and compact ring spinning machines, the fibers must be removed from the drafting system in case of yarn breaks. The set of free fibers formed after yarn break that is called fiber waste is sucked by the suction pipes located directly under the drafting system for each spindle [1].

In addition to fiber waste suction, another technological suction used in compact ring spinning machines is the suction used for compacting. Compacting technology, which is seen as a revolution in ring spinning, provides to produce better quality yarns, have more flexibility in quality of raw materials and higher production amounts. Basically, compact ring spinning machine is modified conventional ring machines with some changes and additions to the drafting system. The idea of compacting, in other words condensed spinning, underlies in minimizing the change in the width of the fiber set. This is done by condensing the fiber flow in the main drafting zone by air suction and by significantly reducing the spinning triangle. Air suction is made from a perforated surface mounted on the line where the fibers flow [3].

The suction pipes for fiber and compacting are connected to the main suction channel in the center of the sections of ring spinning machine. The suction in this channel, i.e. negative pressure, is created by the suction fan located on only one or both sides of the ring machine and the suction motor that drives this fan. The fiber waste that is removed from the drafting system and waste, dust sucked by compacting system is carried by air to the suction fan. The waste that accumulates in a filter just before the suction fan is separated from the exhaust air. While the waste is collected in the waste chamber of the machine, the exhaust air is removed via the exhaust channel and sent to the air conditioning system [1].

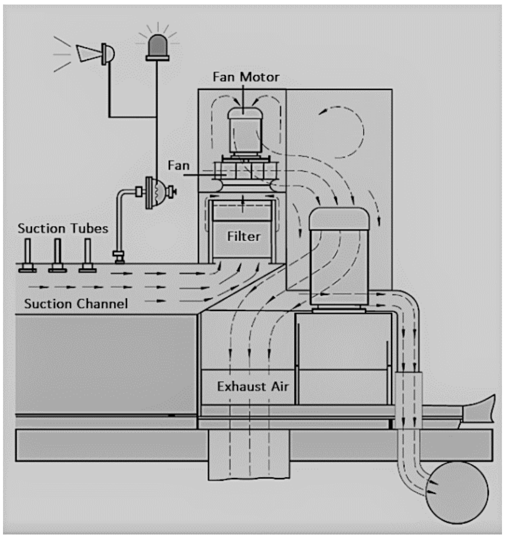


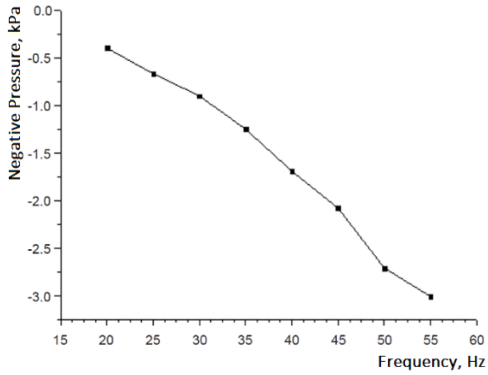
Figure 1. Technological suction in ring spinning machine [1]

In older systems, suction fans and motors that operate at a fixed speed are used. The suction values to be achieved in these systems are fixed and there is no change in fan speeds according to the amount of fiber accumulated in the filter. Negative pressure, which is more than needed, causes relatively more waste formation and negatively affects yarn formation. To eliminate this situation, modern ring spinning machines are equipped with inverter-controlled suction motors. In this way, the inverter regulates the fan speed according to the amount of waste accumulated in the filter and the amount of suction needed. In these systems, there is a pressure measurement sensor to provide the same negative pressure continuously and this sensor sends continuous data to the inverter and regulates the speed of the fan motor. In this way, energy consumption is reduced and additional good fiber loss is prevented [2].

A relatively high amount of vacuum is required for a reliable fiber waste suction. It should be around 600 - 800 Pascal for cotton and 1000 - 1200 Pascal for synthetic fibers. Air flow rate is generally between 5 and 10 m^3/h. Energy consumption required for fiber waste suction is important. For example, energy consumption at 10 m^3/h is 4.5 times higher than at 6 m^3/h, due to considerably higher vacuum [1].

For the compacting suction, the negative pressure needed can vary between 800 and 3000 Pascal according to the compacting system. Keeping the negative pressure low will change the compacting effect of the yarn and cause deterioration in yarn quality values, especially yarn hairiness value. Keeping it higher than necessary will increase energy consumption.

In modern ring spinning machines, negative air pressure is adjusted by the frequency converter (inverter) that controls the fan motor. The frequency value of the inverter is specified in Hertz (Hz). The relationship graph between frequency value and negative pressure varies according to the power of the fan motor. The Graph 1 shows the relationship between frequency and negative pressure in a compact ring spinning machine (for long staple fiber) for 5.5 kW fan motor [5].



Graph 1. The correlation between negative pressure and frequency [5]

As shown in Graph 1, lower negative pressure amounts can be reached with the high frequency values in the inverter of the fan motor. As the frequency value increases, the energy consumption of the fan motor increases.

In terms of saving in energy consumption, it is important to work with the minimum suction required in ring spinning machines. The importance of this is further understood when it is considered after the spindle drive, which is the main drive in the ring spinning machine, the second most energy consuming part is the fan motor drive, which creates the technological suction.

The ratio of technological suction to the total energy consumption of the ring spinning machine is 12-15% for conventional machines and 12-17% for compact machines [4]. In this regard, the determining of optimum technological suction is important in terms of energy saving.

The aim of the study is to show how much energy can be saved by decreasing the technological suction amount of the ring machine and draws the attention of both academic researchers and spinning mills. The fact that there is no source related to the subject in the literature indicates that the study will be important in terms of eliminating the deficiency in the literature.

2. Material and Method

In this study, the energy saving achieved by minimizing the technological suction amount was demonstrated without compromising the requirements. It was carried out on both compact and conventional ring spinning machines.

The energy measurements made within the scope of the study were grouped into two main sections. In the first one, the energy consumption of only fan motor was measured at different frequency values (Hz) and how the energy consumption changes were revealed, while the machines were not in production and the filter is completely clean. The measured values were compared in kilowatt-hours (kWh). The ammeter was used for the measurements. In the other group measurements, the observations were done, while ring spinning machines were in full production. It was investigated how the energy consumption required per 1 kg yarn production was changed when the fan motor inverter's frequency value was 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 analyzer and integrated current transformers were used in the measurements.

The technical features of the ring machines, which energy measurements were made, are given in Table 1.

Table 1. Technical specifications of ring spinning machines

Machine no	Machine 1	Machine 2
Type of ring spinning machine	Conventional	Compact
Spindle quantity	1824	1632
Installed power of fan motor	6,5 kW x 2 motors	6,5 kW x 2 motors
Fan motor	Inverter controlled	Inverter controlled
Double or single-sided suction	Double-sided	Double-sided
Compacting system	No	Yes, perforated drum system
Compact suction	No	Common suction with fiber waste suction

During energy measurements, three different measuring devices were used. The details of related devices are given below, and images are given in Figure 2.

Three-phase energy analyzer: 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.

Ammeter: It is a device that measures the current intensity of the electric current, that is, the amount of current passing through the conductor.

Three-phase current transformers integrated in the ring 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 machine. Energy consumption data can be obtained from the screen of the ring machine or from mill monitoring systems connected to the ring machines. More than 1 year of data can be obtained from facility monitoring systems and software [4].

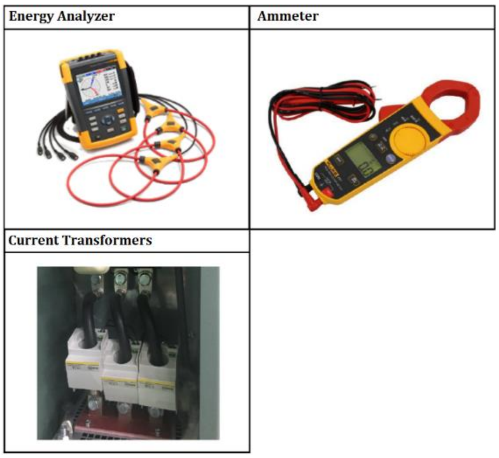


Figure 2. Energy measuring devices [4]

3. Results

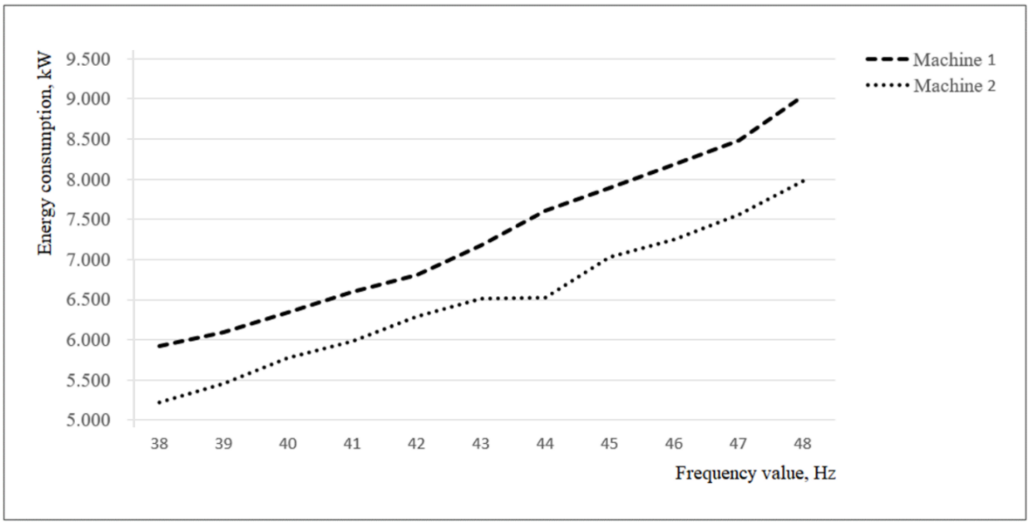
While conventional and compact ring machines were not producing (idle) and their filters were completely clean, the energy consumption of only fan motor was measured at different frequency values. The results were given in Table 2 and 3 below. At both tables, total energy consumptions of fan motors were given in kWh for each increased frequency value. Additionally, the energy increase was shown in percentage and kWh compared to one lower frequency value and lowest frequency value i.e., 38 Hz.

Table 2. Fan motor energy consumption according to inverter frequency value – Machine 1

Suction motor frequency value (Hz)	Energy consumption of fan motors (kWh)	Energy increase compared to the lowest frequency value (%)	Energy increase compared to the lowest frequency value (kWh)	Energy increase compared to one lower frequency value (%)	Energy increase compared to one lower frequency value (kWh)
38	5.922				
39	6.090	2.84%	0.17	2.84%	0.17
40	6.342	7.09%	0.42	4.14%	0.25
41	6.594	11.35%	0.67	3.97%	0.25
42	6.804	14.89%	0.88	3.18%	0.21
43	7.182	21.28%	1.26	5.56%	0.38
44	7.602	28.37%	1.68	5.85%	0.42
45	7.896	33.33%	1.97	3.87%	0.29
46	8.190	38.30%	2.27	3.72%	0.29
47	8.484	43.26%	2.56	3.59%	0.29
48	9.030	52.48%	3.11	6.44%	0.55

Table 3. Fan motor energy consumption according to inverter frequency value – Machine 2

Suction motor frequency value (Hz)	Energy consumption of fan motors (kWh)	Energy increase compared to the lowest frequency value (%)	Energy increase compared to the lowest frequency value (kWh)	Energy increase compared to one lower frequency value (%)	Energy increase compared to one lower frequency value (kWh)
38	5.225				
39	5.457	4.44%	0.23	4.44%	0.23
40	5.779	10.60%	0.55	5.90%	0.32
41	5.982	14.49%	0.76	3.51%	0.20
42	6.296	20.50%	1.07	5.25%	0.31
43	6.507	24.54%	1.28	3.35%	0.21
44	6.523	24.84%	1.30	0.25%	0.02
45	7.032	34.58%	1.81	7.80%	0.51
46	7.249	38.74%	2.02	3.09%	0.22
47	7.557	44.63%	2.33	4.25%	0.31
48	7.972	52.57%	2.75	5.49%	0.42



Graph 2. Energy consumption according to frequency value

As shown in Table 2, 3 and Graph 2, the energy consumption increase of the fan motor is in direct proportion with the increase of the frequency of the fan motor in both compact and conventional ring spinning machines. Based on the results of the measurements made on machines 1 and 2, the following findings were reached.

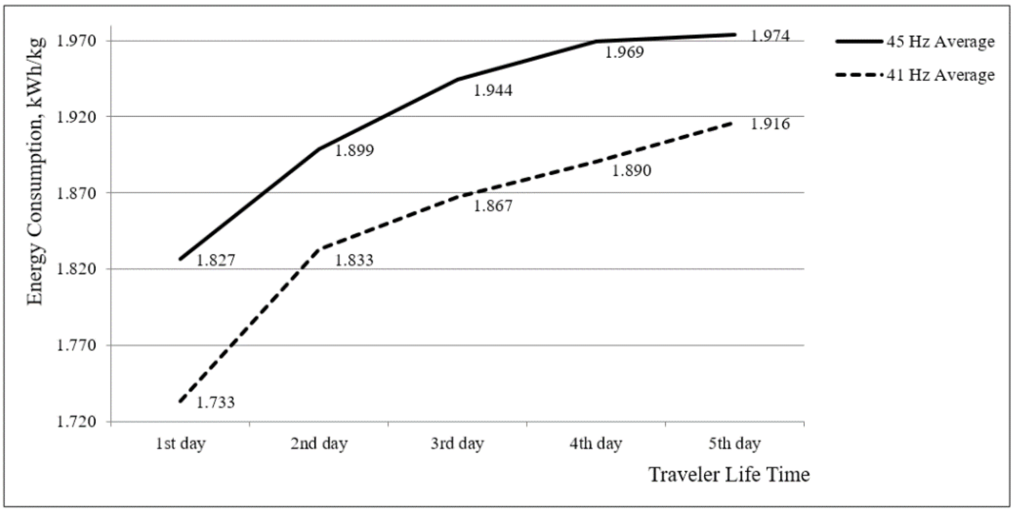
- Each Hz increase in frequency was resulted an average of 0.29 kilowatt-hours of energy consumption increase.
- As a percentage rate, each Hz increase in frequency value was caused an average energy increase of 4.3% in fan energy consumption.
- The technological suction constitutes 12-17% of the total energy consumed in the production of 1 kg of yarn [4]. From this point of view the conclusion of the energy consumption required for 1 kg of yarn production increases by 0.5-0.73% in each Hz increase of fan motor frequency was reached.

Furthermore, it was aimed to compare above mentioned results with the results to be obtained when the ring spinning machine is in full production. Accordingly, the energy measurements were also made on conventional and compact ring machines while machines were in full production.

In a conventional ring machine (Machine 1), while running 65/35% Polyester/Viscose blends, 3 measurements were made for each frequency value. During all 3 measurements yarn count was Ne 40/1, yarn twist was 920 T/m and average spindle speed was 17370 rpm. Comparative energy measurements were made by using integrated current transformers by trying to keep all other parameters constant. By changing the frequency of the inverter of the fan motor from 45 Hz to 41 Hz, the change in energy was measured during the first five days traveler lifetime. The results were given in Table 4 and Graph 3.

Table 4. The change of energy consumption according to frequency value – Machine 1

Frequency Value	Traveler Life Time	Energy Consumption (kWh/kg) 1st day	2nd day	3rd day	4th day	5th day	Average	Difference 41 vs 45 Hz (%)
45 Hz	Measurement A	1.830	1.935	1.945	1.961	1.998	1.934	
	Measurement B	1.872	1.921	1.975	2.013	1.968	1.950	
	Measurement C	1.778	1.840	1.913	1.934	1.955	1.884	
	Average	1.827	1.899	1.944	1.969	1.974	1.923	
41 Hz	Measurement A	1.736	1.801	1.835	1.861	1.892	1.825	
	Measurement B	1.774	1.862	1.907	1.913	1.946	1.880	
	Measurement C	1.689	1.835	1.860	1.897	1.911	1.838	
	Average	1.733	1.833	1.867	1.890	1.916	1.848	-3.880%



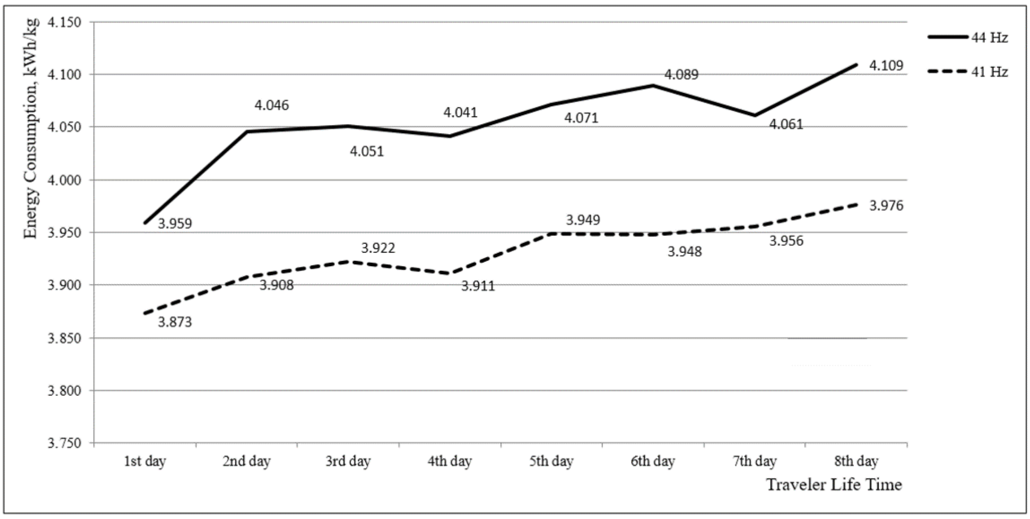
Graph 3. The change of energy consumption according to frequency value - Machine 1

As shown in Table 4; it was observed that the average energy consumption of 3 measurements decreased from 1,923 kWh/kg to 1,848 kWh/kg with the frequency reduced to 41 Hz. In other words, a decrease of 4 Hz in the frequency of the fan motor provided an average saving of 3.88% in total energy consumption. When this decrease per frequency value was considered; the conclusion of the decrease in frequency value of 1 Hz provides 0.97% saving in total energy consumption was reached.

In a compact ring machine (Machine 2), the measurement was also carried out for each frequency value in a 100% Combed Cotton working ring spinning mill. Each measurement was based on yarn count Ne 60/1, yarn twist 1197 T/m and average spindle speed 23457 rpm. The comparative energy measurements were made from the same roving by trying to keep all other parameters constant and using integrated current transformers. The change on energy was followed when the frequency value of the fan motor was changed from 44 Hz to 41 Hz. The measurements were conducted during the 8-day long traveler lifetime. The results were given in Table 5 and Graph 4.

Table 5. The change of energy consumption according to frequency value - Machine 2

Frequency Value	Energy Consumption (kWh/kg) Traveler Lifetime (day)									Difference
	1st	2nd	3rd	4th	5th	6th	7th	8th	Average	41 vs 44 Hz (%)
44 Hz	3.959	4.046	4.051	4.041	4.071	4.089	4.061	4.109	4.053	
41 Hz	3.873	3.908	3.922	3.911	3.949	3.948	3.956	3.976	3.930	-3.035%



Graph 4. The change of energy consumption according to frequency value - Machine 2

As shown in Table 5; with the fan motor frequency value reduced from 44 Hz to 41 Hz, it was observed that the amount of energy required per kg of yarn production has decreased from 4,053 kWh/kg to 3,930 kWh/kg. In other words, 3,035% average saving in energy consumption was achieved. So, the conclusion was reached that the decrease in frequency value of 1 Hz provides 1.01% saving in total energy consumption.

Based on the comparative energy measurement results made when the machines were in full production, the result of the total energy consumption required per kg yarn decreases by 1% with each Hz decrease in the frequency of the fan motor was obtained.

This is valid in both compact and conventional ring spinning machines.

4. Discussion and Conclusion

In the study, it was determined the amount of technological suction's effect to the total energy consumption in both compact and conventional ring spinning machines. The observations were made when the ring spinning machines are idle and in full production.

As a result of energy measurements, it was found out that with each Hz decrease in the frequency of the fan motor, the saving in total energy consumption per 1 kg yarn was 0.50-0.73% when the machine was idle. Energy saving was around 1% when the machine in full production.

If the results were compared when the machines were idle and in full production, the conclusion was reached that the increase of each frequency step is 0.27-0.50% more when the machine in full production. The reason is the loss in the negative pressure. In other words, the air resistance created by the fiber waste in the suction pipes, the main suction channel, the filter, and the compacting equipment causes more losses in the negative pressure and the fan motor starts to work higher frequency value in order to reach the minimum required negative pressure. Accordingly, the energy consumption increases more.

The results were shown that the amount of technological suction significantly changed the energy consumption of the ring spinning machine and the determining of optimum technological suction amount is important in terms of energy savings. When these results were evaluated for a spinning mill with 20 ring spinning machines with 1632 spindles; it was seen that annual energy savings of 15.75-17.5 MW per machine and 315 - 350 MW per mill can be achieved thanks to decreasing of the suction amount.

In this context, it is obvious that the amount of technological suction should be taken into consideration in terms of energy saving, especially in spinning plants where there are conventional and compact ring machines with inverter-controlled fans. Since there is no similar study in the literature, the results obtained in the study could not be compared. However, in this context, it is obvious that the study contributes to the literature.

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