PART 1: IMPACT OF TUBE WEIGHT ON RING FRAME POWER CONSUMPTION

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Abstract: *In ring spinning mill 40% to 45 % energy is consumed by ring spin department alone, of which 70% to 80% energy is consumed by spindle motor. Saving energy has become an area of great importance in the textile industry as in every field. The aim of this study is to evaluate the impact of ring tube (yarn carrier) weight with respect to energy consumption in ring yarn manufacturing systems. This study also elaborates energy saving possibilities with respect to selection of yarn carriers. This study compared energy consumption with 3 different tube weight (40 g, 25 g and 17 g) with and without yarn formation keeping the same yarn content.*

Results indicated that the energy consumption (kWh) for bare tube running (without yarn) is 0.74% to 2.52% higher compared to the bare machine running without any tubes on the spindle. But the energy consumption difference increased from 2.85% to 5.2% when yarn produced. With the lower tube weight higher difference in energy consumption was observed. The slim tube (17 g and 25 g) produced by using lower density composites provided significant energy saving. Compared to 40 g standard tubes 25 g and 17 g tubes showing approx. INR 20 Lakhs and INR 36 Lakhs and above saving per year respectively for a 25536-spindle plant. This project study will help textile spinning industry leaders to choose slim tubes a better choice for optimising performance, minimising cost of yarn production per kg.

Keywords: Ring spinning, Ring tube weight, Energy saving, Yarn content, UKG.

1. Introduction

The power required to drive the spinning frame is in most instances an appreciable component of the cost of producing spun yarns. In the determination of the optimum package size when re-equipping a spinning, it was found that power consumption is the principal increasing cost to be set against the reduced handling costs [1]. Ring frame section consumed 47.12% of total installed power capacity of the spinning plant. Humidification is the second largest power consumer area which is less than one fourth of the ring frame section. Any saving of energy even in a smaller percentage would have a greater impact on the total electricity bill of the spinning mill [2]. The annual consumption of energy for a 30,000-spindle capacity spinning mill is about 10 million units (kWh), which works out to over Rs. 4.0 crores per year. Potential savings from energy at about Rs. 200 per spindle per year is almost the same as the net profit margin a spinning mill can earn under normal trading conditions [3].

Total ring-frame power can conveniently be divided into two main headings i.e. spindle power and ancillary power. Spindle power further divided into primary power and secondary power. Primary power consists of two major components that is spinning power and package power. Secondary power relates to the power transmission to run the spindle by means of tape and tin rollers in ring frame machine [1]. Power consumed to produce yarn by the rotation of spindle is known as spinning power and the extra power required to drive the package weight on the spindle is termed as package power during yarn formation. As the package weight is lowest at the start of ring spinning cycle the package power is low, but as the yarn wounded gradually on ring tube, the package power consumption increases as the cop becomes larger [4]. The ancillary power (being only of the order of 10% of the total) is very much less important than the total spindle power [1]. Spinning power and package power are only variables with cop build up and are important power consumption areas in ring frame machine. Machine manufactures and researchers are continuously doing research to reduce the power consumption at ring frame at different areas but reduction in package power consumption by reducing the package (tube) weight is the main aim of this study.

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 [5]. 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%. In the ring spinning machine, 70-80% of the energy is consumed by the spindle motor [3]. 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. A very few research works was found on impact of tube weight on ring frame power consumption may be due to non-availability of slim tube i.e., tube weight lesser than standard tube used in industry.

In a recent study, COŞKUN et al (2022) compared effect of tube weight on energy consumption and found positive results, but in that study, machines of different spindle capacity, different count sets at different speeds were used [6]. Due to this, the impact of tube weight on energy consumption was not prominent. So, in this research, except tube weight, all other parameters like spindles per machine, spindle speed, yarn count were fixed to analyse impact of slim tubes on the energy saving of ring frame. Effect of cop content on energy consumption was also investigated in another study.

The bare machine (without ring tubes on spindle without yarn formation) load of a textile ring spinning machine refers to the amount of power it consumes while operating. It includes the power needed to drive various components such as the spindle, drafting system, and other auxiliary systems. The running load can vary depending on factors such as the type and size of the machine, the materials being spun, and the operating parameters. For a specific machine, the running load can be measured using a power meter or calculated based on the electrical specifications provided by the manufacturer. It's an important parameter to monitor as it affects energy consumption and production efficiency. Lower running loads can indicate more efficient operation and lower operating costs.

Bare machine running conditions without tube on spindle without yarn formation the power consumption should be minimum. Because spindle motor requires less torque for the initial start. Thereafter, to keep rotating at set speed less power is consumed as spindle bearings load and frictional losses in transmission of drive consumed less power. To verify this phenomenon, study was conducted with three different tube weight with and without yarn formation keeping the cop content constant.

2. Materials and Methodology

Materials

Ring tubes are made from different material in specific dimensions. The most common running size of ring frame tube in the industry is 190 mm tube length with 18 mm bottom inner diameter with 36 to 40 g weight. So, in this study 40 g tube wight was taken as standard along with 25 g and 17 g tube weight. The tube specifications are given in Table 1. All tubes were procured from M/S Moksha Thermoplastics Pvt ltd. Ahmedabad, Gujarat India**.** 17 g tube weight bobbins are not available commercially in market. Thanks to M/S Moksha Thermoplastics Pvt ltd. Ahmedabad, Gujarat India for preparing a special lot for this research.

Table 1. Selected tubes materials and specifications.

S. N.	Tube Length, Dui* & Taper Ratio	Tube Thickness (mm)	Material used	Weight (g)	Flexural Strength for 1 mm deflection (kg_f)
1	190 /18 / 1:64	3	Poly Carbonate	40	33.68
2	190 /18 / 1:64	1.5	PAGF / M53 / M102**	25	31.61
3	190 /18 / 1:64	1	M103	17	26.55

*Dui means Diameter under inner i.e. bottom inner diameter.

**M53, M102, M103 are referred to equivalent material composition recipe in the respective category by Moksha Thermoplastics Pvt Ltd. Ahmedabad, Gujarat India.

Methodology

Power Consumption Measurement at Ring Frame

To measure the power consumption of a ring frame an energy meter was connected to the main power supply of that ring frame for a doff. Rieter K42 ring frame was selected in this study. M/S Slivertech Fibers Pvt. Ltd. allowed for this study. Energy meters typically displays the energy consumption in kilowatt-hours (kWh). The energy meter continuously integrates this power measurement over time to calculate the total energy consumed. The picture of energy meter and Rieter K42 display is shown in Figure 1. All the experiments were conducted on same ring frame.

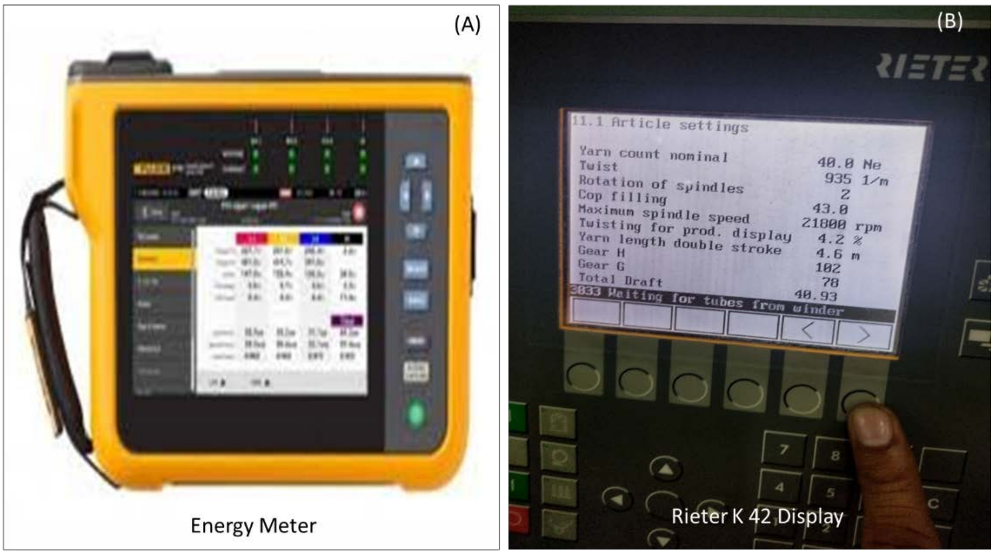

Figure 1. Picture of Energy meter and Rieter K 42 Display.

Ring Frame Parameters

For research work involving ring frame spinning, it's crucial to maintain certain key parameters constant to ensure the reliability and validity of experimental results. These parameters typically include machine configuration, fiber type and fiber blend, environmental conditions, process parameters, and sampling and analysing parameters. Keeping the ring frame machine configuration consistent throughout the research helps in eliminating variability stemming from different machine setups. This includes maintaining consistent settings for drafting systems, spindle speeds, traveller sizes, and other machine-specific parameters. Table 2 showing the ring frame spinning parameters used in this study.

Table 2. Rieter Ring Frame K42 Parameters.

S.N.	Parameter	Detail
1	Yarn Count	40 CWC
2	TPI	26.3
3	Ring Diameter	36 mm
4	Spindle Capacity	1824
5	Chase Length	42 mm
6	Spindle Motor	110 KW
7	Drafting System	3/3
8	Traveller	R&F C1HDW8/0
9	Average Spindle Speed	21000
10	Maximum Spindle Speed	21800
11	Standard Doff Time	142 min

Testing

Testing of Ring Tubes

Different test was performed as per the industry norms. The detail of each test is mentioned below. The results are summarised in Table 1.

- *Thickness Gauge*
  Mechanical thickness gauge with minimum count capacity of 0.1 mm is used to measure wall thickness of tubes. Thickness was measured at three places i.e. at 10 mm from top and bottom, in the middle.
- *Weighing Balance*
  Weighing balance of minimum capacity of 0.1 g was used to measure weight of tubes.
- *Vernier Calliper*
  A digital vernier calliper of least count of 0.01 mm is used for measurement of tube length and diameter.
- *Flexural strength*
  The flexural strength test for textile spinning ring tubes assesses the tube's ability to withstand bending forces, which is critical for its performance and durability during spinning operations. Flexural strength test was formed as shown in Figure 2D.

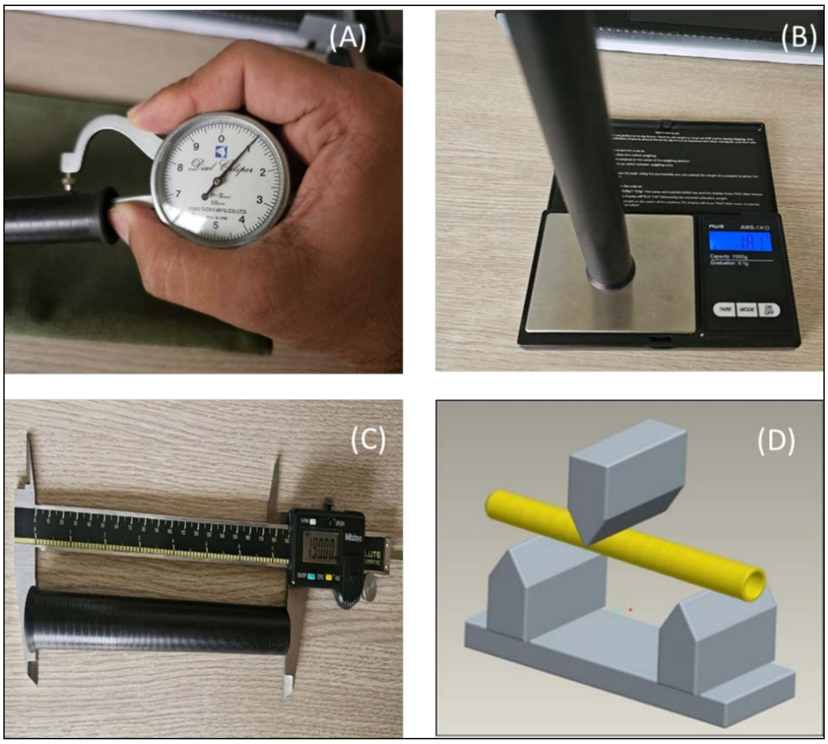

Figure 2. Testing instruments for ring frame tubes.

Statistical Analysis

Statistical Analysis investigate and validates trends, pattern, relationship in the experimental data. This research is field study type. Tube weight and cop content were taken as explanatory variables with 3 levels each. 10 trials were conducted for each experiment. Arithmetic mean and standard deviation were calculated for all the results. Power consumption in terms of kilowatt hour (kWh) and Unit consumed to produce per kilogram of yarn (UKG) were subjected to linear regression analysis. Analysis of variance (ANOVA) was also conducted to analyse the significance of regression coefficient at 0.05 and 0.1 levels of significance. ANOVA single factor was analysed for statical significance between tube weight and energy consumption.

3. Result and Discussion

In this study, the focus of research is to find the impact of tube weight on ring frame power consumption. So, power consumption was measured with and without yarn formation on ring frame. At first, energy consumption of ring frame machine without bobbin i.e. bare spindle was measured as well as bare machines while running with varying tube weights. The aim was to understand the direct impact of tube weight on energy consumption by changing the tube weight thereby optimizing operational efficiency. Following this, energy consumption was measured while yarn manufacturing with varying tube weight. This investigation allowed to identify the relationship between tube weight and energy efficiency, facilitating informed decisions regarding machine configuration. The detailed results are highlighted in further sections.

Energy Consumption for Bare Machine Running with Varying Tube Weight

Bare machine running conditions whereby spindle and tube rotates as unibody, and the differential load created by varying tube weight affects energy consumption of ring spinning machine. The power consumption at bare machine running along with without bobbins are given in Table 3. In the Table 3, energy consumption for bare machine running i.e. without yarn formation is measured. Average energy consumption of 130.69 kWh was recorded when no yarn formation without tubes on the spindle machine run for 142 minutes at 21000 rpm. This is the power required for the rotation of bare machine. When 40g tubes loaded on the spindle, the energy consumption measured was 134.24 kWh, which is 2.71% higher compared to the bare machine running for the same 142 minutes duration. The energy consumed for 25 g tube weight was 132.36 kWh which is 1.35% higher than the bare machine running condition and 1.32% lower than the 40 g tubes energy consumption. With 17 g tubes without yarn formation, energy consumption measured was 131.73 kWh which is 0.795% higher than bare machine running (without tube on spindle) and 1.869% lower than the energy consumption with 40g tubes on the spindle. The difference in energy consumption is clearly visible in Figure 3.

Table 3. Comparison of energy consumption for bare machine running with varying tube weight.

Parameters	**Bare Spindle Running**	**Standard Tubes**	**Slim Line Tubes**	**Slim Line Tubes**
Avg. Spindle Speed (rpm)	21000	21000	21000	21000
Tube Weight (g)	NA	40	25	17
Tube Thickness (mm)	NA	3	1.5	1
Tube Length (mm)	NA	190	190	190
Machine run time (minute)	142	142	142	142
Power consumed (kWh)	130.69 ± 0.36	134.24± 0.46	132.47± 0.54	131.74± 0.29
UKG	NA	NA	NA	NA
Energy saving %	NA	2.71%	1.35%	0.795%

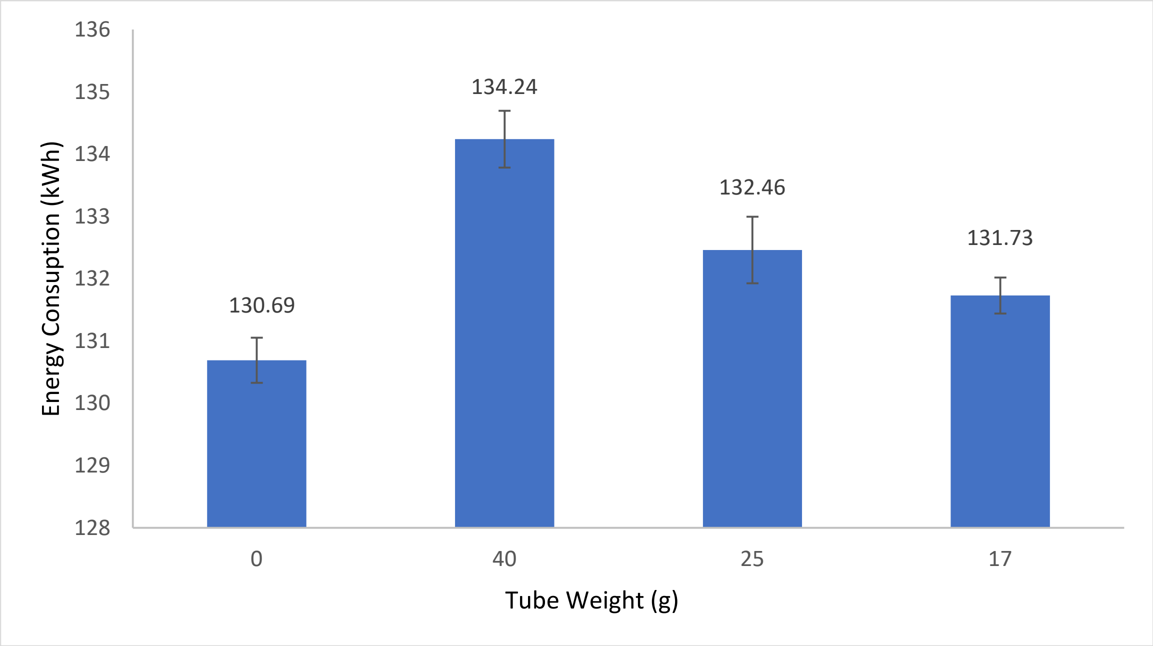

Figure 3. Energy consumption for bare machine running with varying tube weight.

The possible reason behind this major difference in energy consumption is the initial torque required to gain the set speed with differential loads on the spindle motor. Once the set spindle speed is achieved than to keep rotating spindle a very small energy consumption is required as due to momentum the spindle keep rotating further. For example, large turbine continues rotation with small energy to keep rotating. These results indicated that tube weight is directly proportional to energy consumption at ring frame without yarn formation. Therefore, lower tube weight is recommended but slim tube below 25 g are not available in market commercially. However, 17 g tube weight produced by M/S Moksha Thermoplastic Pvt. Ltd. will be commercially used in future after investigating its durability and cost.

Highly positive linear correlation (R^2 = 0.96) was found between tube weight on ring frame power consumption (Figure 3.4). From single factor ANOVA analysis (Table 3.4) it is clear that impact of tube weight on ring frame power consumption is statistically significant (F=61.70, $p<0.05$).

Table 4. Statistical analysis for the effect of tube weight on ring frame power consumption without yarn formation (Linear Regression and ANOVA).

R^2	SS	MS	F	Significance F
0.96	6.49	6.49	61.70	0.015*

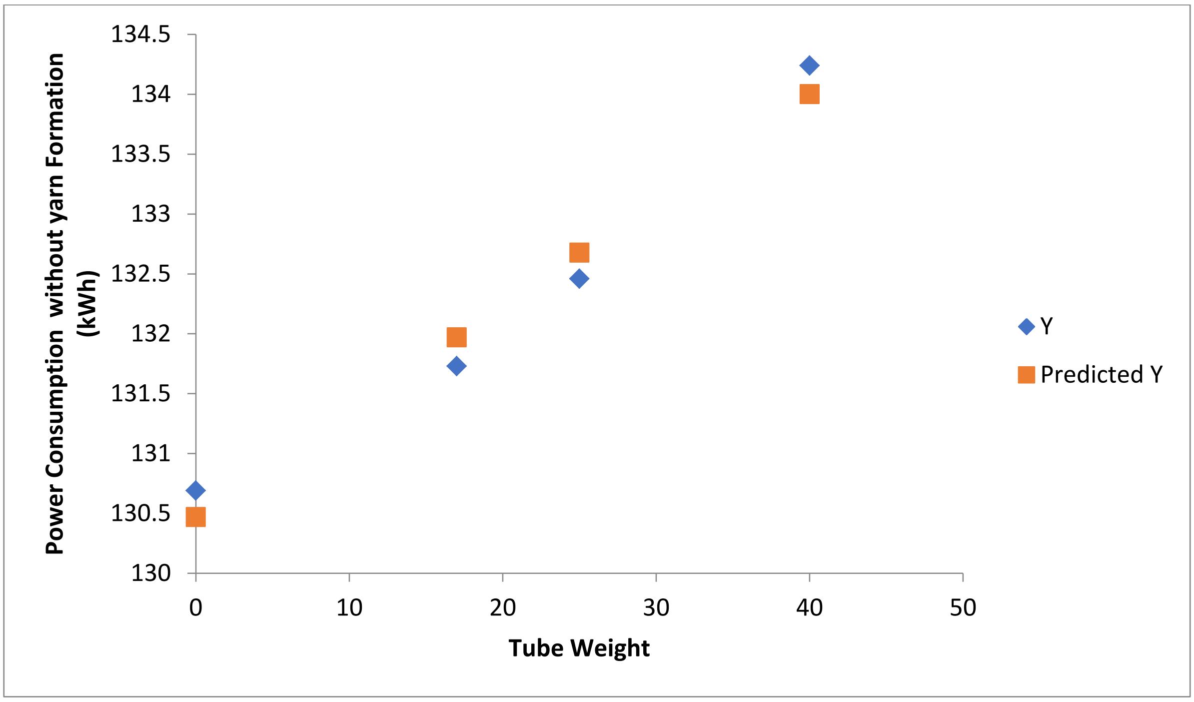

Figure 4. Correlation between Tube weight and Power Consumption without yarn formation.

Energy Consumption for Yarn Forming Machine with Varying Tube Weight

During yarn formation yarn weight, yarn drag force, air resistance, yarn tension etc play important role in energy consumption along with continuously increasing cop content on ring tube at ring frame. Table 5 represents the energy consumption data with yarn formation at 21000 rpm avg. spindle speed for 142 minutes of a doffing cycle on the ring spinning machine. Energy consumption of 169.65 ± 0.83 kWh was recorded with 40 g standard ring tube. While 75.98 ±0.25 kg yarn was manufactured in one doff delivering 2.233 UKG. However, 164.8± 0.47 kWh and 160.8± 0.74 kWh energy were consumed for the similar production/doff in 25 g and 17 g tube respectively. Slim tubes of 25 g weight consumed

2.85% lower energy than the power consumption with 40 g standard tubes. Similarly, slim tubes of 17 g weight consumed 5.21% lower energy than 40 g standard tubes. The UKG for 25 g and 17 g tube weight is 2.169 and 2.117 respectively which are lower than 40g standard tube weight.

Table 5. Comparison of energy consumption for yarn forming m/c by varying tube weight.

Avg. Spindle Speed (rpm)	21000	21000	21000
Tube Weight (g)	40	25	17
Tube Thickness(mm)	3	1.5	1
Tube Length (mm)	190	190	190
M/c run time(minutes)	142	142	142
Power consumed (KWH)	169.65 ± 0.83	164.8± 0.47	160.8± 0.74
Production / doff (Kg)	75.98 ±0.25	75.98 ±0.36	75.97 ±0.34
UKG	2.233	2.169	2.117
Energy difference (Delta)	NA	2.85%	5.21%

Approximately 39 kWh i.e. 23.5 % energy consumed due to spinning and package weight for 40 g standard weight tube compared to bare machine power consumption i.e. 130.69 kWh or say without yarn formation (Figure 5). But due to slim tubes the energy saving is approximately 5 kWh/doff/machine and 9 kWh/doff/machine for 25 g and 17 g tube weight respectively which is higher than the power consumed due to bare bobbin machine running (Figure 6). The possible reasons behind this major difference in energy consumption may be the initial torque required to gain the set speed with differential loads on the spindle motor and continuously low weight on spindle including yarn as well as tube weight.

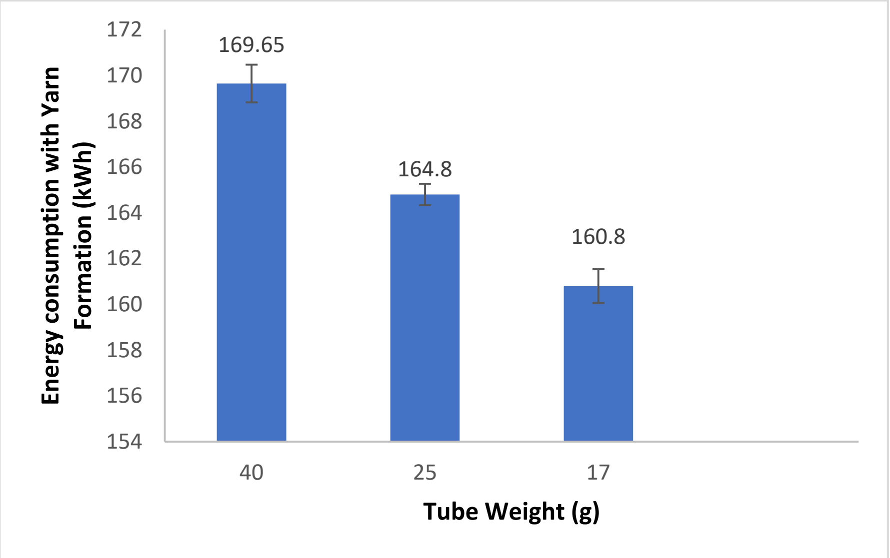

Figure 5. Energy consumption for bare machine running with varying tube weight.

These results indicated that lower tube weight enhance the power saving with yarn production at ring frame than without yarn production. Highly positive linear correlation (R^2 = 0.986) was found between tube weight on ring frame power consumption with yarn formation (Figure 7). From single factor ANOVA analysis (Table 6) It is clear that impact of tube weight on ring frame power consumption is statistically significant (F=70.49, p<0.1).

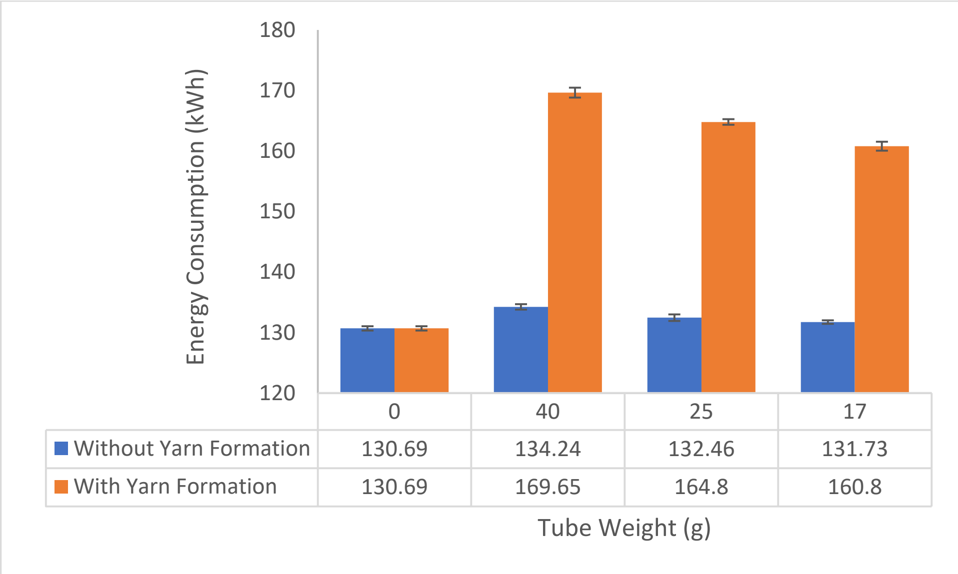

Figure 6. Comparison of energy consumption with and without yarn formation.

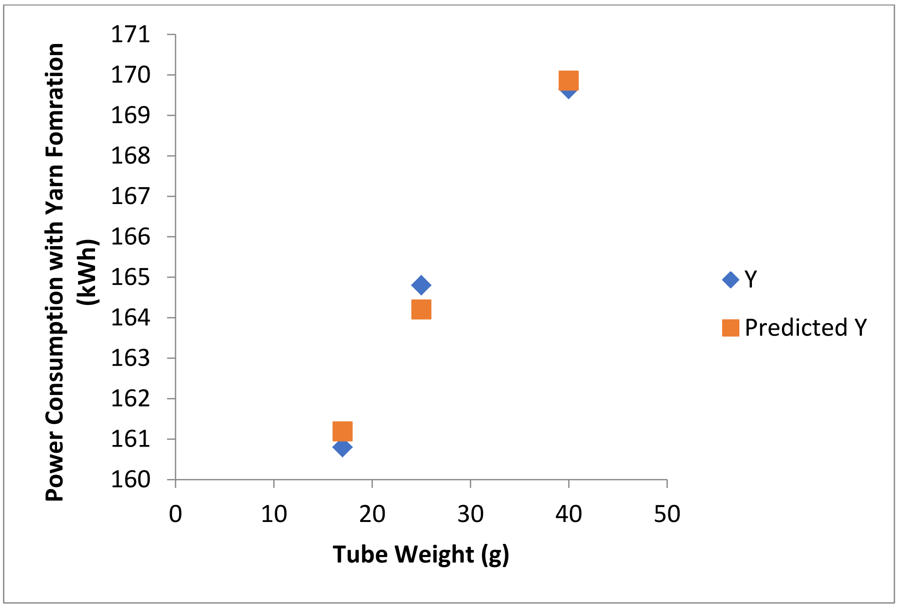

Figure 7. Correlation between Tube weight and Power Consumption with yarn formation.

Table 6. Statistical analysis for the effect of tube weight on ring frame power consumption with yarn formation (Linear Regression and ANOVA).

R^2	SS	MS	F	Significance F
0.986	38.73	38.72	70.49	0.075*

When tubes of 40 g weight are loaded on the spindle for a 1824 spindle machine, more power is required for rotation of spindle having a total of 72.96 kg tube weight compare to 45.60 kg and 31 kg with 25 g and 17 g tube weight respectively. These comprehensive comparisons provided valuable insights for enhancing energy efficiency in textile manufacturing operations.

Potential Energy Saving at Ring Frame due to Slim Tubes

From the above discussion, it is clear that slim tubes help in power saving. To make it clearer that how much power saving can be possible in term of INR, a brief detail is mentioned in Table 7.

Table 7. Potential energy saving with 25 g and 17 g tube weight at ring frame.

Tube weight (g)	40 g	25g	17g
Spindle Capacity	1824	1824	1824
M/c doffing cycles time (minutes)	142	142	142
Number of doffs/year/machine	3448	3448	3448
Yarn production / doff / m/c (kg)	75.98	75.98	75.98
Yarn production / year / m/c	261970	261970	261970
Energy consumed / doff	169.65	164.8	160.8
Energy consumed / year/machine (kWh)	584934	568212	554420
UKG	2.233	2.169	2.116
Cost per unit (INR)	8.55	8.55	8.55
Cost of energy /machines / year (INR)	5001186	4858211	4740293
Cost of energy/25536 spindles (INR)	₹ 7,00,16,610	₹ 6,80,14,956	₹ 6,63,64,108
Energy savings for 25536 spindle / year (INR)		₹ 20,01,654	₹ 36,33,848
Productivity difference (%)		0.00	0.00

Compared to 40 g standard tubes vis a vis 25 g and 17 g tubes showing that with the use of slim tubes with equal yarn content INR 20 Lakhs and INR 36 Lakhs and above can be saved respectively. This is significant for a 25536-spindle plant.

4. Conclusion

Ring spinning machines operating under bare running conditions, the impact of tube weight on energy consumption is evident. Notably, the relationship between tube weight and energy usage is directly proportional. For instance, with smaller weight tubes such as 17 g tubes, energy consumption remains minimal, at only 0.795%. However, this disparity grows significantly with heavier tubes; for 40 g tubes, the energy consumption rises to 2.71%. Thus, as tube weight increases, so does the energy consumption, suggesting a clear correlation between these variables.

With yarn formation, the energy saving is higher for slim tubes of 17 g and 25 g compared to standard tubes of 40 g. These data highlight the energy consumption, production, and efficiency metrics for different tube weights in a ring spinning machine. As the tube weight decreases, there's a trend of lower energy consumption and higher efficiency, with the most significant energy savings observed between the 40g and 17g tubes. The UKG is lower for 17 g tubes compared to 25 g and 40 g tubes keeping the cop content constant. Compared to 40 g standard tubes 25 g and 17 g tubes showing approx. INR 20 Lakhs and INR 36 Lakhs and above saving per year respectively for a 25536-spindle plant. 2nd part of this research will discussed the impact of cop content along with cop weight on ring frame power consumption.

Acknowledgment

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