AN EXPERIMENT TO ANALYZE THE IMPACT OF STEAM ON THE PRODUCTIVITY OF THE STALAM RF 85 KW YARN DRYER

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Abstract: Radio Frequency is one of the most commonly used technologies in the processing industries like textile, rubber, paper and many other sectors for drying purposes. The RF STALAM 85kW is a machine used to dry the yarn obtained after the dyeing and hydro extraction process. This machine uses radio frequency to remove the moisture content from the dyed yarn. In this research paper, I would like to share the findings of an experiment conducted on the RF STALAM 85kW yarn dryer machine. In this experiment, I have three trials each with and without the steam at variable conveyor belt speeds. The trials have been conducted at conveyor belt speeds of 5m/hr,5.5m/hr and 6m/hr in the presence and absence of steam. The primary objective of the research is to improve the productivity of the STALAM RF machine. The secondary objective of the research is to find out the impact of steam on the yarn drying ability of the machine. The tertiary objective of the research is to find the optimum speed. At the end of the experiment, I calculated the per day production to conclude the optimum speed to run the STALAM RF 85kW yarn drier machine to obtain maximum production with and without steam. From the above research, I have concluded that the conveyor belt speed and steam increase the productivity of the machine.

Keywords: STALAM RF, radio frequency, yarn dyeing, drying, yarn, production, textile engineering, manufacturing

1. INTRODUCTION

Radio Frequency (RF) Yarn Dryers are popular in the textile industry. They remove the moisture content from the yarn cheese obtained after dyeing and hydro extraction. STALAM is an Italian company well known all across the globe for its cutting-edge technology in radio frequency equipment. These RF Yarn Dryers are used to dry cotton, acrylic and polyester blend yarns. A high-frequency electric field (nearly 2.7 MHz) will be generated inside the RF Machine. This high-frequency electric field will affect the dielectric nature of the moisture absorbed by the yarn. It causes a molecular disturbance and the water molecules evaporate from the yarn. The STALAM RF Yarn Dryer Machine is shown in Figure 1. An RF STALAM Yarn Dryer has four main parts. They are as follows:

1. Inlet Section: In the inlet section, the operator places the yarn cheese cones obtained after dyeing and hydro extraction on the conveyor belt.
2. Drying Section: The radio waves with a frequency as high as 2.7MHz is generated in this section. The drying of the yarn happens inside the drying section.
3. Outlet section: The dried yarn comes out of the drying section. The operator can use the yarn for the forthcoming operations.
4. Control Panel: The control panel is used to control the conveyor belt speed, radio frequency power and other operating parameters.

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Fig. 1. STALAM RF Yarn Dryer.

The five main advantages of the RF STALAM Yarn Dryer are as follows [1]:
1. The machine enables a faster rate of yarn drying.
2. The machine allows the firm to increase its production of dried yarn.
3. The machine provides Energy-saving benefits.
4. The machine has almost no maintenance problems.
5. The machine has a compact design.

In the book titled "Drying in the Process Industry" [2], the author described the working principle of the RF Dryer and its three main installation configurations. They are as follows two flat metal plate configurations, stray field electrode system and staggered through field electrode system. In the book titled "High Frequency and Microwave Heating. In Fundamentals of Electroheat." [3], the author explains the importance of radio frequency in the textile and processing industries. The RF Dryers have enabled textile industries to adopt sustainable means of manufacturing [4]. Despite the initial high setup cost, the RF Dryer enables a fast and effective dying [5]. The implementation of the ERP Database to the PLC of the RF STALAM enables the faster calculation of the automatic tape speed and electrode level based on the raw weight of the wet coil [6]. The Radio Frequency (RF) drying has an ability to remove nearly 50% to 60% of the moisture [7]. The bending and twisting of the textile play a vital role in analyzing the impact of the RF on the fabric [8]. It is proven that the RF Dryers improve the productivity of the machine and improve the quality of product without missing out on the production targets [9]. Drying sized textile warp yarns using the RF technology is a bit expensive but it tends to improve the quality and finishing of the weaving fabric [10]. A very small proportion of radio frequency energy is being diffused as compared to the heat energy obtained from a fossil fuel source for drying in the textile industry [11]. In the research paper titled "RADIO-FREQUENCY DRYING OF TEXTILES", the advantages and disadvantages of the RF drying in a textile industry have been highlighted. The energy loses associated with "indirect heating" has been minimized. The heat developed due to the radio frequency is directly proportional to the moisture content [12]. A thermal and mechanical drying system test rig for yarn bobbins was designed by the researchers. In this configuration, the yarn bobbins were dried using hot air. A quality index of 92% was achieved by passing air at a temperature of 120 degree Celsius on the yarn for a period of 6 hours [13]. Drying of the yarn at high temperatures might affect the strength of the yarn and would lead to breakages in the forthcoming steps [14]. Cylindrical arrangement of cotton yarn will enable a gentle and rapid drying of the yarn in the drying machine [15]. Over drying of yarn has led to yarn damage at creep speed [16]. The usage of radio frequency energy to dry yarn has been proven as an economical option than the conventional means of heating [17]. The researchers proved that factors like diameter of the bobbin, drying temperature, drying pressure and volumetric-flow of air play a vital role in the yarn-drying process using a hot-air bobbin dryer [18]. The radio frequency waves are more advantageous as compared to the microwaves for drying yarn. A machine using radio frequency is less complex and economical than a machine using microwaves [19].

2. EXPERIMENTAL SETUP

The main aim of the experiment is to calculate the optimum speed to run the STALAM RF 85kW yarn drier machine to obtain maximum production. The experiment was conducted on the STALAM RF 85kW Yarn Dryer at the Himatsingka Linens Process Plant. The length of the machine is 9 m. The width of the machine is 2.4 m. The height of the machine is 3.3m. The machine was manufactured in the year 2006. The maximum RF Power value has been set at 65kW. The experiment has two phases. They are as follows:

1. *Phase One:* In the first phase, three trials were conducted on the Fair-Trade White Yarn (1/16 s) count without the supply of steam to the RF Yarn Dryer Machine at conveyor belt speeds of 5 m/hr, 5.5 m/hr and 6.0 m/hr.
2. *Phase Two:* In the second phase, three trials were conducted on the Fair-Trade White Yarn (1/16s) count with the supply of steam to the RF Yarn Dryer Machine at conveyor belt speeds of 5 m/hr, 5.5 m/hr and 6.0 m/hr.

In each trial under each phase, 10 randomly selected yarn cheese cones are weighed before and after being put into the RF Yarn Dryer machine. Then the production calculations are done. The trials were conducted at Himatsingka Linens at Hassan in Karnataka during my tenure as a Graduate Engineer Trainee from March 2022 to June 2022. The project work was supervised by Mr Nithyananda U M and Mr Ashok M Wade of the Engineering Department in association with the Yarn Dyeing Department of the Himatsingka Linens Process Plant. The yarn cheese cones were provided by the Himatsingka Fibers. All the safety protocols were followed while executing the trials.

Fair-Trade White Yarn is chosen for the experiment because it is one of the commonly used dyed yarn in the Himatsingka Terry Plant. The count of the yarn is 1/16s. The grey weight of the yarn cone before dyeing is 1.2 kg. The yarn cheese cones are subjected to hydra extraction using a hydra extractor before being dried on the STALAM RF Machine (Figure 2).

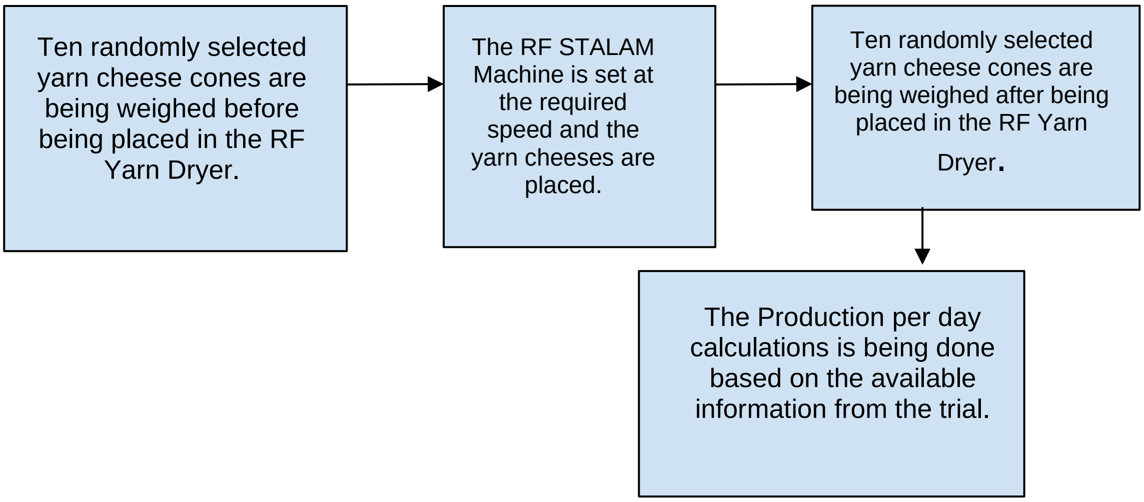

Fig. 2. The trial methodology.

3. METHODOLOGY

3.1. Phase one of the experiment

In the first phase, three trials were conducted on the Fair-Trade White Yarn (1/16s) count without the supply of steam to the RF Yarn Dryer Machine at conveyor belt speeds of 5 m/hr, 5.5 m/hr and 6.0 m/hr. The steps involved in conducting each trial are as follows:

1. Ten randomly selected yarn cheese cones are weighed.
2. The average weight of yarn cheese cones must be calculated.
3. 60 g of cone weight must be subtracted from the average weight.
4. The grey yarn weight (1.2 kg) is subtracted from the answer obtained in the 2nd Step.
5. The answer obtained in the 3rd Step is multiplied by 24 (i.e., number of yarn cheese cones placed per meter on the conveyor belt) to get the moisture to be removed.
6. The speed is calculated based on the formula mentioned below:

$$Speed = \frac{1.2 * Maximum\ RF\ Power\ Value(kW)}{Mositure\ to\ be\ removed\ from\ 24\ Yarn\ Cheese\ Cones} \quad (1)$$

7. The electrical connections and power supply to the RF Stalam Yarn Drying machine are checked. The machine is switched on.
8. The maximum RF Power is set to 65 kW and the desired speed is also set on the Control Panel.
9. The randomly selected 10 yarn cheese cones are numbered and then placed on the conveyor belt.

10. The numbered 10 yarn cheese cones after being dried in the RF Yarn Dryer are weighed.

Three trials have been executed at conveyor belt speeds of 5 m/hr, 5.5 m/hr and 6 m/hr by adhering to the above-mentioned steps. The results obtained in Phase 1 without steam at speeds of 5 m/hr, 5.5 m/hr and 6 m/hr have been tabulated in Table 1, Table 2 and Table 3.

Table 1. Trial 1 at speed 5.0 m/hr without steam.

Sl Number	Original Grey Cheese Weight(kg)	Initial Weight Before RF Dryer (kg)	Final Weight After RF Dryer (kg)	Weight Loss (kg)
1	1.200	1.8450	1.120	0.7250
2	1.200	1.8600	1.145	0.7150
3	1.200	1.9250	1.190	0.7350
4	1.200	1.7800	1.130	0.6500
5	1.200	1.7850	1.100	0.6850
6	1.200	1.8100	1.125	0.6850
7	1.200	1.7800	1.115	0.6650
8	1.200	2.1000	1.305	0.7950
9	1.200	1.8000	1.120	0.6800
10	1.200	1.7800	1.110	0.6700
Total	12.000	18.4650	11.460	7.0050
Average Weight (kg)	1.200	1.847	1.146	0.701
Cone Weight (kg)		0.0600		
Average Weight Without the Cone (kg)		1.7865		
Grey Weight of The Yarn Cheese (kg)		1.2000		
Moisture To Be Removed Per Cheese (kg)		0.5865		
Moisture to be removed for 24 Cheese (kg)		14.076		

Table 2. Trial 2 at speed 5.5 m/hr without steam.

Sl Number	Original Grey Yarn Cheese Cone Weight(kg)	Initial Weight Before RF Dryer (kg)	Final Weight After RF Dryer (kg)	Weight Loss In The RF(kg)
1	1.200	1.7450	1.115	0.6300
2	1.200	1.7200	1.100	0.6200
3	1.200	1.7050	1.110	0.5950
4	1.200	1.7900	1.120	0.6700
5	1.200	1.7100	1.110	0.6000
6	1.200	1.7500	1.120	0.6300
7	1.200	1.7400	1.110	0.6300
8	1.200	1.7250	1.095	0.6300
9	1.200	1.7050	1.075	0.6300
10	1.200	1.7200	1.115	0.6050
Total	12.000	17.3100	11.070	6.2400
Average Weight (kg)	1.200	1.731	1.107	0.624
Cone Weight (kg)		0.0600		
Average Weight Without the Cone (kg)		1.6710		

Grey Weight of The Yarn Cheese (kg)		1.2000		
Moisture To Be Removed Per Cheese (kg)		0.4710		
Moisture to be removed for 24 Cheese (kg)		11.304		

Table 3. Trial 3 at speed 6.0 m/hr without steam.

Sl Number	Original Grey Yarn Cheese Cone Weight(kg)	Initial Weight Before RF Dryer (kg)	Final Weight After RF Dryer (kg)	Weight Loss (kg)
1	1.200	1.7550	1.150	0.6050
2	1.200	1.7400	1.125	0.6150
3	1.200	1.7800	1.250	0.5300
4	1.200	1.7800	1.145	0.6350
5	1.200	1.8100	1.135	0.6750
6	1.200	1.8400	1.145	0.6950
7	1.200	1.7750	1.150	0.6250
8	1.200	1.8300	1.140	0.6900
9	1.200	1.7600	1.140	0.6200
10	1.200	1.7450	1.125	0.6200
Total	12.000	17.8150	11.505	6.3100
Average Weight (kg)	1.200	1.782	1.151	0.631
Cone Weight (kg)		0.0600		
Average Weight Without the Cone (kg)		1.7215		
Grey Weight of The Yarn Cheese (kg)		1.2000		
Moisture To Be Removed Per Cheese (kg)		0.5215		
Moisture to be removed for 24 Cheese (kg)		12.516		

3.2. Phase two of the experiment

In the second phase, three trials were conducted on the Fair-Trade White Yarn (1/16s) count with the supply of steam to the RF Yarn Dryer Machine at conveyor belt speeds of 5 m/hr, 5.5 m/hr and 6.0 m/hr. The steps involved in conducting each trial are as follows:

1. The steam line is set up with 6 divergent nozzles each being provided at the inlet and outlet. The steam pipeline has a dia 1 inch. The nozzles have an outlet diameter of 2 mm.
2. The steam is supplied at 1.0 Bar pressure and at a temperature of 120 ºC.
3. The steam flow for the RF Yarn Dryer is activated by opening the valves.
4. Ten randomly selected yarn cheese cones are weighed.
5. The average weight of yarn cheese cones must be calculated.
6. 60 g of cone weight must be subtracted from the average weight.
7. The grey yarn weight (1.2 kg) is subtracted from the answer obtained in the 2nd Step.
8. The answer obtained in the 3rd Step is multiplied by 24 (i.e., number of yarn cheese cones placed per meter on the conveyor belt) to get the moisture to be removed.
9. The speed is calculated based on the formula mentioned in equation (1).
10. The electrical connections and power supply to the RF Stalam Yarn Drying machine are checked. The machine is switched on.
11. The maximum RF Power is set to 65 kW and the desired speed is also set on the Control Panel.
12. The randomly selected 10 yarn cheese cones are numbered and then placed on the conveyor belt.
13. The numbered 10 yarn cheese cones after being dried in the RF Yarn Dryer are weighed.

Three trials have been executed at conveyor belt speeds of 5 m/hr, 5.5 m/hr and 6 m/hr by adhering to the above-mentioned steps. The results obtained in Phase 2 with steam at speeds of 5 m/hr, 5.5 m/hr and 6 m/hr have been tabulated in Table 4, Table 5 and Table 6.

Table 4. Trial 1 at speed 5.0 m/hr with steam.

Sl Number	Original Grey Yarn Cheese Cone Weight(kg)	Initial Weight Before RF Dryer (kg)	Final Weight After RF Dryer (kg)	Weight Loss (kg)
1	1.200	1.8500	1.125	0.7250
2	1.200	1.8000	1.125	0.6750
3	1.200	1.8550	1.135	0.7200
4	1.200	1.8050	1.115	0.6900
5	1.200	1.9400	1.200	0.7400
6	1.200	1.8800	1.225	0.6550
7	1.200	1.8800	1.200	0.6800
8	1.200	1.8950	1.150	0.7450
9	1.200	2.1950	1.345	0.8500
10	1.200	1.8150	1.115	0.7000
Total	12.000	18.9150	11.735	7.1800
Average Weight (kg)	1.200	1.892	1.174	0.718
Cone Weight (kg)		0.0600		
Average Weight Without the Cone (kg)		1.8315		
Grey Weight of The Yarn Cheese (kg)		1.2000		
Moisture To Be Removed Per Cheese (kg)		0.6315		
Moisture to be removed for 24 Cheese (kg)		15.156		
Calculated Speed Based on The Formula (1.2 x Max RF Value/ Moisture to be removed for 24 Cheese)		5.146476643		

Table 5. Trial 2 at speed 5.5 m/hr with steam.

Sl Number	Original Grey Yarn Cheese Cone Weight(kg)	Initial Weight Before RF Dryer (kg)	Final Weight After RF Dryer (kg)	Weight Loss (kg)
1	1.200	1.9050	1.185	0.7200
2	1.200	1.8750	1.175	0.7000
3	1.200	1.8500	1.155	0.6950
4	1.200	1.8600	1.145	0.7150
5	1.200	1.9250	1.165	0.7600
6	1.200	1.8950	1.190	0.7050
7	1.200	1.8650	1.160	0.7050
8	1.200	1.9600	1.205	0.7550
9	1.200	1.8900	1.170	0.7200
10	1.200	1.7900	1.100	0.6900
Total	12.000	18.8150	11.650	7.1650
Average Weight (kg)	1.200	1.882	1.165	0.717
Cone Weight (kg)		0.0600		

Average Weight Without the Cone (kg)		1.8215		
Grey Weight of The Yarn Cheese (kg)		1.2000		
Moisture To Be Removed Per Cheese (kg)		0.6215		
Moisture to be removed for 24 Cheese (kg)		14.916		
Calculated Speed Based on The Formula (1.2 x Max RF Value/ Moisture to be removed for 24 Cheese)		5.22928399		

Table 6. Trial 3 at speed 6.0 m/hr with steam.

Sl Number	Original Grey Yarn Cheese Cone Weight(kg)	Initial Weight Before RF Dryer (kg)	Final Weight After RF Dryer (kg)	Weight Loss (kg)
1	1.200	2.0450	1.300	0.7450
2	1.200	2.1050	1.300	0.8050
3	1.200	2.0600	1.270	0.7900
4	1.200	2.0650	1.300	0.7650
5	1.200	2.1000	1.270	0.8300
6	1.200	2.0550	1.285	0.7700
7	1.200	2.0150	1.270	0.7450
8	1.200	2.0050	1.280	0.7250
9	1.200	1.9900	1.285	0.7050
10	1.200	2.0100	1.265	0.7450
Total	12.000	20.4500	12.825	7.6250
Average Weight (kg)	1.200	2.045	1.283	0.763
Cone Weight (kg)		0.0600		
Average Weight Without the Cone (kg)		1.9850		
Grey Weight of The Yarn Cheese (kg)		1.2000		
Moisture To Be Removed Per Cheese (kg)		0.7850		
Moisture to be removed for 24 Cheese (kg)		18.84		
Calculated Speed Based on The Formula (1.2 x Max RF Value/ Moisture to be removed for 24 Cheese)		4.140127389		

4. DISCUSSIONS

To find the optimum speed for maximum production, we will have to calculate the per day production based on the data obtained from the 3 trials each conducted in phase one and phase two in the absence and presence of steam respectively. The production per day would be calculated considering that the RF STALAM Yarn Dryer only runs for 22 hours a day and 24 yarn cheese cones are kept per meter. The three main production parameters calculated are as follows:

1. Total Weight of Input Yarn for Drying in 22 Hours (kg): The total input into the RF Yarn Dryer Machine was calculated using the equation (2).

$$\text{Total Weight of Input Yarn(kg)} = \text{Speed}\left(\frac{\text{m}}{\text{hr}}\right) \cdot 22\text{hr} \cdot 24 \cdot \text{Average Input Yarn Weight(kg)} \quad (2)$$

2. Total Weight of Yarn Dried In 22 Hours (kg): The output from the RF STALAM Yarn Dryer Machine is estimated using this parameter. It is calculated by using equation (3). This parameter would be used to find the optimum conveyor belt speed for maximum production.

$$\text{Total Weight of Yarn Dried In 22 Hours(kg)=Speed}\left(\frac{\text{m}}{\text{hr}}\right) \cdot 22\text{hrs} \cdot 24 \cdot \text{Average Output Yarn Weight} \quad (3)$$

3. Total Weight of Moisture Removed In 22 Hours (kg): The moisture removed from the yarn in RF Yarn Dryer Machine is calculated using equation (4).

$$\text{Total Weight of Moisture Removed In 22 Hours(kg)=Speed}\left(\frac{\text{m}}{\text{hr}}\right) \cdot 22\text{hrs} \cdot 24 * \text{Average Moisture Removed} \quad (4)$$

Table 7. The Production per day at Speeds 5 m/hr, 5.5 m/hr and 6 m/hr without steam.

Speed (m/hr)	Average Weight of The Input Yarn for Drying During the Trial (kg)	Average Weight of Yarn Dried During the Trial (kg)	Average of Moisture Removed During the Trial (kg)	Total Weight of Input Yarn for Drying in 22 Hours (kg)	Total Weight of Yarn Dried in 22 Hours (kg)	Total Weight of Moisture Removed in 22 Hours (kg)
5	1.847	1.146	0.7005	4876.08	3025.44	1849.32
5.5	1.731	1.107	0.624	5026.824	3214.728	1812.096
6	1.782	1.151	0.631	5645.376	3646.368	1999.008

From Table 7, it's clear that the at a speed of 6m/hr a maximum production of 3646.368 kg per day is achieved while the least production has been achieved by running the machine at a speed of 5m/hr. We must also note that the total moisture removed per day depends not only on the speed but also on the quality of the yarn being dyed.

The graph between Total Daily Production Without Steam v/s Speed has been shown in the Figure 3. The horizontal axis has Speed measured in m/hr and the vertical axis has the Total Weight of Yarn Dried in 22 Hours measured in kilograms.

When we compare the data from Table 7 and Table 8, we can clearly say that the Total Weight of Yarn Dried in 22 hours has been increased significantly due to the impact of steam. Even under the influence of steam, the maximum production is achieved when the machine is running at 6 m/hr. The difference between the maximum per-day production obtained with and without steam is 420 kg. The moisture removed per day under the influence of steam is higher than the moisture per day without steam.

The graph between Total Daily Production with Steam v/s Speed has been shown in the Figure 4. The horizontal axis has Speed measured in m/hr and the vertical axis has the Total Weight of Yarn Dried In 22 Hours measured in kilograms. Table 9 represents the difference in production achieved with and without steam.

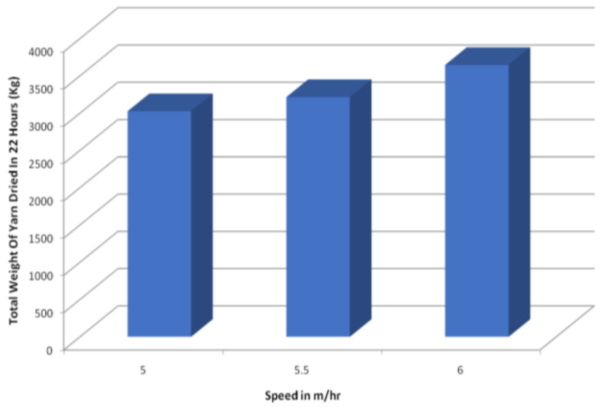

Fig. 3. Total Weight of Yarn Dried In 22 Hours (kg) v/s Speed(m/hr) [Without Steam].

Table 8. The production per day at speeds 5 m/hr, 5.5 m/hr and 6 m/hr with steam.

Speed (m/hr)	Average Weight of The Input Yarn for Drying During the Trial (kg)	Average Weight of Yarn Dried During the Trial (kg)	Average of Moisture Removed During the Trial (kg)	Total Weight of Input Yarn for Drying in 22 Hours (kg)	Total Weight of Yarn Dried in 22 Hours (kg)	Total Weight of Moisture Removed in 22 Hours (kg)
5	1.892	1.174	0.718	4994.88	3099.36	1895.52
5.5	1.882	1.165	0.717	5465.328	3383.16	2082.168
6	2.045	1.283	0.7625	6478.56	4064.544	2415.6

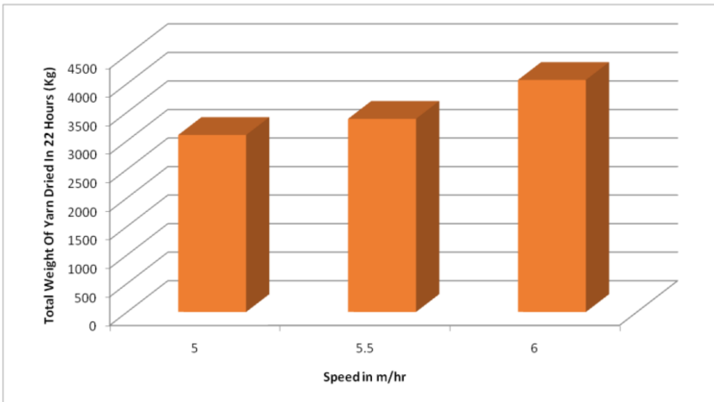

Fig. 4. Total weight of yarn dried in 22 Hours (kg) v/s speed(m/hr) [With Steam].

Table 9. The difference in production with and without steam.

Speed (m/hr)	Total Weight of Yarn Dried In 22 Hours (kg) Without Steam	Total Weight of Yarn Dried In 22 Hours (kg) With Steam	Increase In Production (kg)	Percentage Increase in Production (%)
5	3025.44	3099.36	73.92	2.385008518
5.5	3214.728	3383.16	168.432	4.978540773
6	3646.368	4064.544	418.176	10.28838659

7.CONCLUSIONS

The trials were conducted as per the above-mentioned steps. All safety protocols were adhered to while conducting the trials on the RF STALAM machine. The following conclusions can be drawn from the above experiment. They are as follows:

1. The production of the RF STALAM Yarn Dryer Machine has increased significantly due to the impact of steam.
2. The lowest output of dried yarn with and without steam has been achieved at a conveyor belt speed of 5 m/hr.
3. The maximum output of dried yarn with and without steam has been achieved at a conveyor belt speed of 6 m/hr.
4. There were no instances of tripping being reported at speeds of 5 m/hr, 5.5 m/hr and 6 m/hr.
5. The conveyor belt speed plays a very important role in deciding the production of the machine.
6. There have been instances of multiple tripping when the RF STALAM machine has been running at speeds greater than 6 m/hr. The reasons for tripping are as follows:
   I. The triode becomes overheated due to the ambient temperature conditions.
   II. There’s the excessive load being applied on the triode when there’s an increase in the number of yarn cheeses being kept for drying on the conveyor belt.
   III. The age of the triode tends to affect the performance of the machine.

7. In all the trials, the ambient temperature was 30°C to 35°C. Only 24 yarn cheeses were kept per meter on the conveyor belt. There was no increase in load. The only reason tripping occurred in the machine is due to the age of the triode.
8. To get increase the daily production, the triode valve must be replaced with a new one from the Original Equipment Manufacturer (OEM) so that the machine can run at higher conveyor belt speeds without tripping.
9. The machine must be run at 6m/hr to get the maximum daily production without any tripping problem.

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