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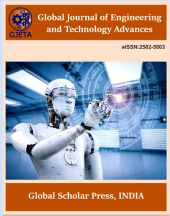

(Research Article)

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Design and fabrication of a cloth dryer

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Abstract

The evolution of drying machine came as a necessity against the traditional method of cloth drying using direct energy from the sun. This necessity is due to the evolution of the earth and change in in environmental conditions resulting from the climate change. The cloth drying machines available in the country are majorly imported and expensive and may not be affordable to average Nigerians. To solve this problem, a cloth drying machine that is affordable was designed and fabricated in the Department of Mechanical Engineering Technology, Federal University of Technology, Akure, Nigeria using locally available materials. The dryer consists of the door, drying chamber, heater, fan, 750 Watts geared electric motor, micro-computer temperature sensor, electrical cables, power transmission devices and the frame. The dryer was tested and found suitable for the task it was developed for at an average drying rate of 0.4 to 1.2 g/min. It was observed that there was a significant reduction in weight of the clothes showing effective moisture removal in the drying process. The dryer is recommended for domestic drying of every category of fabrics.

Keywords: Development; Drying; Drying rate; Fabrics; Time; Weight

1. Introduction

A cloth dryer is a common household appliance used to dry clothes or other fabrics after they have been washed. Mechanically, the drying method involves a low revolution of a turning drum in drying chamber where heat is supplied and adequate air flow is maintained. Usually, this takes place after spinning of wet linen (Shi *et al*., 2015). Cloth washing and drying are very essential to life but they are considered undesirable because of the involvement of efforts, time and cost, especially when it comes to drying washed clothes, it then becomes a herculean task when one has a great number of clothes to dry with limited resources (Bhushan and Narendra, 2017)

Traditionally, drying of clothes is usually done in a natural way by using the energy from the sunlight and the wind, but nowadays the technology is well developed and grown, and the cloth dryers which use the electric energy or other energies come into use extensively, especially in the urban area where people who live in tall buildings may not be able to dry clothes using heat energy from the sun (Suntivarakorn *et al*., 2009).

The first electric dryer was invented in the early 20th century by Ross Moore when he was tired of hanging his clothing outside, especially during the winter. To help keep his wardrobe out of the freezing weather, he built a shed to house his clothes while they dried. He added a stove to the shed and the clothing would hang on the line in front of the fire and dry. This was the beginning of the development of electric dryers. For the next three decades, Moore worked and eventually build a gas and electric unit, but couldn't find anyone to help him get his idea manufactured. The drum-type model was built and eventually picked up by Hamilton Manufacturing in Wisconsin. The new dryers were sold under the name June Day in the year 1938. In England and France during the end of the 18th century, clothes dryers were made of metals and named ventilators due to the fact that the dryer's drum had ventilation holes in it that allowed heat

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into it while it was hand cranked over an open fire and this invention was used for decades. America later caught onto the idea of these ventilators, unfortunately, the clothing consistently smelled of smoke, was covered in soot and occasionally caught on fire during the drying process. This wasn't an ideal situation. George T. Sampson of Ohio decided that the ventilator invention needed to be tweaked. Instead of using heat from an open fire, he chose to place a rack over a stove. This heat source was much better, as it didn't dirty the clothing or catch it on fire. On June 7, 1892, Sampson was granted a patent for his idea. These dryers were used well into the 19th century (Malave *et al*., 2017).

Adnot (2000) discussed the adaptability of metal fiber burners to industrial paper and textile drying techniques, but this method of drying of textiles involving evaporation and combustion requires a careful control, high temperature chamber, typically around 600°C. Klöcker *et al*. (2002) reported a laboratory prototype laundry dryer equipped with CO_2 heat pump modified from a commercial hot air laundry dryer but not fabricated. Ameen and Bari (2004) described the utilization of the air conditioner waste heat for drying clothes. They found that the waste heat drying method took about 2 hours compared to 2.5 hours for a commercial dryer. The recovery technique was feasible but the running cost of an air conditioner or heat pump itself was considered as expensive. Torres-Reyes *et al.* (2002) described semi-empirical models for the thermal characterization of an experiment, the result of which was an indirect modeling method derived from the second law of thermodynamics. Suntivarakorn *et al.* (2009) reported a study on clothes dryer using waste heat from split-type RAC. A drying chamber with dimensions of 0.5 m × 0.5 m × 1.0 m was designed and fabricated. An auxiliary fan with power of 180 W was installed to draw hot air from the condenser. Load of the drying chamber was varied. The results showed that the drying rate of clothes using waste heat from air conditioner is between 1.1 kg/h and 2.26 kg/h. This was claimed better than commercial dryer and natural drying. The effects of auxiliary fan were evaluated using decreasing Coefficient of Performance (COP) of the system. However drying characteristics and SMER were not discussed.

There are a wide range of cloth drying machines available in the market but they are very expensive and consume more power and this has made its availability in households to be reduced. The cost of a cabinet dryer either for the domestic or industrial use is far from what the average family class in Nigeria can afford. It is evident that most household would want to have one but for the cost. The degree of poverty in Nigeria is one of the contributory factors why an average Nigerian may not be able to own a dryer. An individual is considered poor in Nigeria if he earns less than 137.4 thousand Nigerian Naira (about 361 U.S. dollars) per year. In total, 40.1 percent of population in Nigeria lived in poverty (Simona, 2020). This work therefore attempt to develop a low cost cloth drying machine which can meet the need of those desiring to dry cloth in a fashion other than the natural cloth spreading in the sun which may be very difficult during raining season.

2. Material and Methods

2.1. Design Considerations

The dryer should be able to

- Hold the clothes
- To withstand the mass of clothes ranging between 1 to 6.5 kg
- Supply heat energy for drying the clothes
- Automatically regulate the temperature
- Reduce the drying rate of fabrics.

2.2. Design Analysis

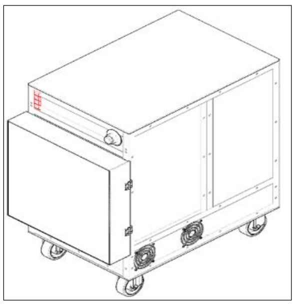

Figure 1 Conceptual diagram of the clothes drying machine

Details of the design of the cloth dryer (Figure 1) is presented above.

2.2.1. Volume of the Drying Chamber

The choice of a cylindrical shape for the drying chamber (Figure 2) was taken to suit the shape of clothes when folded in preparation for drying in a box dryer. An heavy clothe material in its damp state was used as the baseline parameter for the determination of the size.

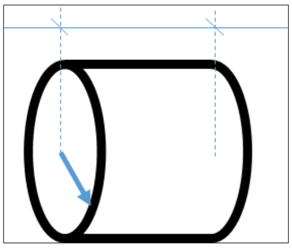

Figure 2 Schematic View of the Drying Chamber

The volume of the drying chamber was therefore determined as 0.1912m^3 using equation 1

$$Volume \ = \pi r^2 \ x \ h……………..(1)$$

Where r is the radius of the chamber and h is the height of the chamber,

A degree of freedom of about 25% of the volume of the clothes was assumed to allow for adequate aeration.

2.2.2. Weight of the Drying Chamber

The weight of the drying chamber was determined as 7.656 kg using equation 2 as derived from the expression below;

Effective Volume (m$^{3)}$ of chamber = (Vol. of Cylinder A – Vol. of Base Circle B) x Density

$$Weight = \{2\pi r^2 h - [2\pi(r-t)(h-t)]\} \times 2.7 \times 1000…………..(2)$$

Where h is the height of the chamber (m), r is the radius of the chamber (m), and t is the thickness of the Aluminum sheet (m).

2.2.3. Torque Requirement

The torque required when the drying chamber is loaded was determined as 0.00125 Nm using equations 3, 4 and 5 (Khurmi and Gupta, 2013)

$$Torque = I \times \alpha \ ……………………..(3)$$

$$I = \frac{M}{2} \times r^2 ………………… (4)$$

$$\alpha = \frac{Change\ in\ Angular\ Velocity(\omega)}{Change\ in\ Time\ taken} \qquad ………………… (5)$$

Where I is the Moment of Inertia, α is Angular Acceleration and r is the Radius of Gyration

2.2.4. Shaft Diameter

The diameter of the shaft was determined using equation 6 as presented below.

Given that one of the objectives of this study was to reduce the consumption of power. A maximum power input of about 1HP (750watt) was proposed for the electric motor.

$$Torque(T) = \sigma \times \pi D^3/16………………… (6)$$

Diameter (D) of the shaft = 0.0288m

= 28.8 mm

Therefore, 30mm shaft was selected

Where; D is the diameter of the shaft and it was the subject of equation; σ is the allowable shear stress.

2.2.5. Clothes Weight and Moisture Analysis.

Weight of clothes and its corresponding moisture content was determined using carried out with a Digital Table Scale and the sundry chart presented in Table 2.

Table 1 Sundry Chart

S/N	Fabrics	Description	Damp (g)	Dry (g)	Mass of Water Removed (g)	Moisture Content %
1.	Cotton	Men singlet	160	110	50	45.45
		Towel	1,013	485	528	108.87
		Quality Ankara	232	170	62	36.47
		Duvet	2596	2203	393	17.84
2.	Jeans	Male Trousers	737	558	179	32.08
3.	Polyester	School Uniform	123	109	14	12.84
		Laboratory Suit	585	345	240	69.57
4.	Chiffon	Women Blouse	117	104	13	12.50
		Women Gown	256	234	22	9.40
5.	Lycra	Women Gown	285	234	51	21.79
6.	Silk	Women Blouse	144	131	13	9.92
		Women Gown	230	193	37	19.17
7.	Lace	Blouse	288	270	18	6.67
		Wrapper	736	670	66	9.85
8.	Nylon	Ankara	176	145	31	21.38
		Sewing Lining	51	45	6	13.33

2.3. Machine Fabrication and Assembly

The components of the cloth dryer were fabricated and assembled at the workshop of the Department of Mechanical Engineering, Federal University of Technology, Akure, Ondo State, Nigeria. The fabrication of the dryer was carried according to the design specifications. Marking out of the steels for fabrication was carried out using a steel rule and a scriber. Operations like cutting, drilling, machining and welding were carried using the appropriate machines as available in the departmental workshop. The components of the dryer were assembled and mounted on the fabricated frame as presented in Figure 3

2.4. Test of the Dryer

The machine was powered to rotate along with the heat source. The temperature control was set to a maximum temperature of 55°Cthat automatically cuts when the sensory probe notices an increase above the set temperature in the drying chamber. The cloth in the drying chamber was removed and its weight taken using an electronic weighing scale (Electronic Kitchen Scale Model: EK4150). Six types of cloth materials were selected in the test because of the variability in the behavior of cotton materials in drying process and the process was repeated for all the cloth samples until the weight of cloth under investigation remained constant or equals to the weight of the cloth in its initial dry condition under sun dry.

The cloth materials selected for the test were Polyester, Chiffon, Silk, Lace, Nylon and Lycra and all the clothes were of the female gown type of same size.

3. Results and Discussion

3.1. Cloth Materials and Drying Rate

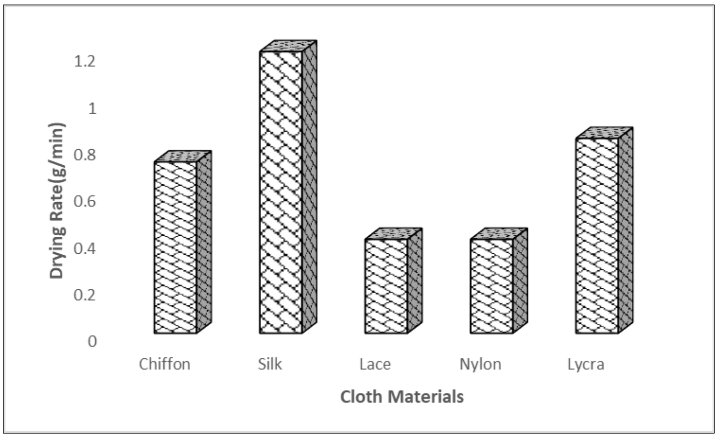

Figure 3 Cloth Materials versus Drying Rate

As presented in Figure 3 it was revealed by the test that the drying rate recorded varied between 0.4 to 1.2 g/min. Silk cloth material had the highest drying rate of 1.2 g/min while nylon and lace materials had the least drying rate of 0.4 g/min. 0.73 and 0.83 g/min were recorded for Chiffon and Lycra respectively. This is in conformity with the study by This is contrary to the claim by Gurudatt *et al.* (2010) that reported that drying rate are independent of the type of, fabric in the constant rate drying. This is also contrary to the report by Cherifi (2017) that claimed that took the longest to dry. The difference in results can be due to difference in type of environment

3.2. Weight-Time Relationship of the Dryer

It was revealed as presented in Figure 4, that the weight of cloth materials decreased with an increase in drying time and later remained constant with further increase in drying time. This is in conformity with Yu *et al. (*2016).that reported similar trend in fabric weight-time relationship. The constant value showed that there was no more moisture in the cloth material in the drying process. The relationship can be described as linear with a coefficient of determination r^2 of 0.8909.

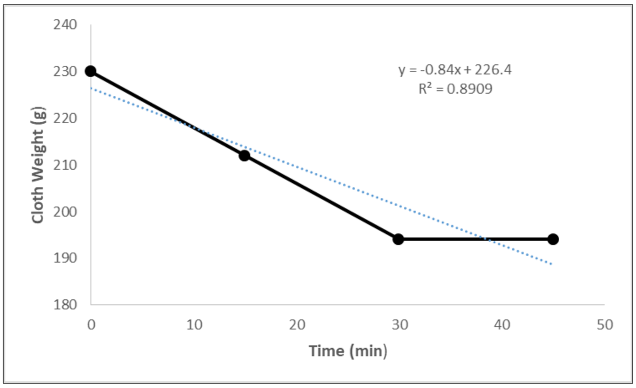

Figure 4 Cloth Weight versus Time

4. Conclusions

The following conclusions were drawn from this study

- A cloth dryer has been designed and fabricated.
- The designed components have been fabricated and assembled.
- The dryer has been tested and found suitable for most of the functional requirements of a fabric dryer.
- The test revealed that the drying rate of the dryer varied between 0.4 to 1.2 g/min for various categories of fabrics

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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