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Development of Unrelaxed Yarn Automatic Cutting Machine

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ABSTRACT

Yarn spinning industry like other manufacturing industries in Nigeria experiences frequent power outages. This, among others, brings about down time as an operator is needed to cut out twisted yarn before the next circle of production commences. In this work, cutting machine was developed using locally available technology and material to automatically cut the twisted yarn after power failure is encountered in yarn spinning process. Experiments were conducted to determine shear load of the acrylic yarn and limiting friction of the pair of scissors used for the design. The results of the experiments conducted showed that the average load required to break the yarn is 2.183N and the limiting friction force is 3.58N. The machine automatically cut the un-relaxed yarn on Univarp - yarn relaxing machine - which accumulates on the conveyer belt due to the flyer motor rotor inertia upon power failure. The mechanical efficiency of the machine was evaluated to be 43.2% and its production cost was fifteen thousand and eighty two naira only.

Introduction

Weaving is one of the oldest of man's industrial arts, and with its allied industrial art of spinning, it led to the industrial revolution. In the late 18th century the first major step towards turning the weaving art into an industry in the modern sense of the term was taken. The factory system began with the textile industry which brought about significant increase in the yardages produced. Generally automation brought about increase in productivity in the textile industry (Chummar *et al.*, 2013). Weaving process involves combining warp and weft components lengthwise and crosswise respectively so as to make a woven structure. The vast majority of woven structures, however, comprise of two sets of apparatus, both flexible and

crossing at right angles. Woven materials include (beside familiar household and apparel textiles) wire screening, fencing, wicker, asbestos cloth, etc. Woven fabrics are made of yarns (long lengths of fibres) which have been drawn out and twisted together.

The yarns are interlaced in a regular order called a binding system, or weave. Most woven textiles are also subjected to one or more finishing processes before they are ready for use.

The machines being used in the textile industry include: Drawing machine, used to make the fibres of the raw material parallel and fine; Roving machine, used to increase the count of the drawn material; Spinning machine, used to spin roved yarn into the required size of sliver and also to increase its count;

Assembly winding machine, used to put spun yarns together in order to meet requirements such as increased strength, increased twisting effect, among others. Other textile machines are: Twisting machine, used to twirl, to coil, assembled slivers so that they do not lay independently and also to improve strength; Bulking machine, sometimes called relaxing machine, used for relaxing yarn before weaving; Univap, a modern type machine use for relaxing yarn.

Baykal *et al.* (2006) conducted research to forecast the elongation and strength properties of cotton/polyester blended rotor yarns. Blended ratios and yarn count were used as predictors in the study. Simplex lattice design with replications at each design point was used to determine the combinations of fibre mixture ratio.

Strumillo *et al.* (2004) designed a yarn spinning model based on the use of neural networks. The yarns were manufactured from flax/cotton blended sliver using BD 200S rotor spinning machine.

Taher *et al.* (2009) studied the influence of spinning parameters and recovered fibres from cotton waste on the uniformity and hairiness of rotor spurn yarn. The results of their work showed that, the effect of rotor parameters (such as diameter and form) and that of rotor speed is as momentous as that of waste proportion.

Power outages are being experienced frequently by Nigerian industries. Ultimately, due to the inertia of the flyer motor rotor of the Univap, the flyer lays some loops of the un-relaxed yarn on the conveyor. These loops are waste because when power is back the flyer and the conveyor cannot move until the loops are removed and if they are forced to move, the loops cannot pass through the guide aperture after

relaxation to the winder frame. This results to down time and also eventual reduction in the productivity of the industry.

This work is aimed at development of a cutting machine using locally available technology and material to automatically cut the twisted yarn after power failure is encountered in yarn spinning process. The machine would help in reducing down time due to power failure and also to minimise quantity of waste generated due to power failure. In essence an enhanced productivity would be achieved using this locally fabricated unrelaxed yarn automatic cutting machine.

Materials and Methods

Materials

Experiments

Experiments were conducted to determine design parameters and material properties that are not readily available in the literature. These are the shearing load of the yarn and friction between the yarn and the scissors.

An experiment was conducted to determine the minimum shearing load of the yarn. The materials used for the experiment are: weight hook, set of weights, plane assembly, sample yarn, two knurled nuts and scissors.

The materials used in the experiment conducted to determine the limiting frictional force between the blades of the sample scissors and the yarn are: weight hook, set of weights, plane assembly, two knurled nuts and scissors.

Construction

The machine was constructed using 2 mm thick mild steel sheets, helical compression spring, M6 stud, 2.5 mm diameter mild steel wire, 12V dc solenoid, 12V dc , 8 pin based timer relay and 240V ac, 8 pin based control relay.

The method here is basically subdivided into the experimental methodologies and the methods or the procedures for the design and construction of the machine.

Experimental Procedures

a. Shear Load of the Acrylic Yarn

As stated earlier, experiments were conducted to determine properties of materials and design parameters required that are not readily available in the literature. The shear load of the acrylic yarn was determined by passing the yarn between the two, open blades of the scissors, just touching the blades. Weight hanger was then attached to the moving arm of the scissors. Weights were then gently loaded until the yarn broke. The procedure was repeated three times.

b. Limiting Frictional Force between the Blades of the Sample Scissors

The second experiment involved the determination of limiting friction force between the blades of a sample scissors. It involved putting a weight hanger on the movable arm of the scissors while the blades are half way opened. Weights were then gently loaded until the blades began to close. The procedure was repeated three times.

Design and construction of the machine

i. Design

The automatic cutting machine basically consists of a double lever (two blades, one fixed and the other movable), slider blocks, compression spring, solenoid, timer relay and a general purpose control relay. Basic procedures of engineering design were followed to design/select the various components of the automatic cutting machine.

The major formulae used for the design of the machine components include:

$$F = m \times a \tag{1}$$

Where: F = force; m = mass; a = acceleration.

Moment

$$F_1 d_1 = F_2 d_2 \tag{2}$$

Where: F₁ and F₂ are forces and d₁ and d₂ are perpendicular distance.

The coefficient of static friction is defined by an equation of the form (Bolton, 1993).

$$\mu_s = \frac{f}{R} \tag{3}$$

Where:

μ_s = coefficient of static friction; f = limiting frictional force; R = Normal reaction.

The direct stress is governed by an equation of the form:

$$\sigma = \frac{F}{A} \tag{4}$$

Where:

σ = Direct stress; F = Force, A = Area

The spring of the automatic cutting machine was designed using equations 5 through equation 14.

$$OD = D_m + D_w \tag{5}$$

$$ID = D_m - D_w \tag{6}$$

Where:

D_m = Mean diameter; OD = Outside diameter; ID = Inside diameter

D_w = Wire diameter.

$$L_s = D_w(N_a + 2) \tag{7}$$

Where:

N_a = number of active coils,

L_s = the solid length of the spring.

$$F_s = K(L_f - L_s) \tag{8}$$

Where:

K = Spring rate

L_f = the free length of the spring.

$$K = \frac{F_{sp}}{L_s} \tag{9}$$

Where:

F_{sp} = Force exerted;

L_s = Spring deflection

$$C = \frac{D_m}{D_w} \tag{10}$$

Where: C - Spring index

$$\tau = \frac{8\kappa f c}{\pi D_w^2} \tag{11}$$

$$\kappa = \frac{4C - 1}{4C - 4} + \frac{0.615}{C} \tag{12}$$

τ is the maximum shear stress which occurs at the inner surface of the spring's wire.

$$Y = \frac{8 F D_m N_a}{G D_m^4} \tag{13}$$

Where:

Y = linear deflection of the spring;

N_a = number of active coils;

G = Modulus of rigidity of the material of the wire.

$$N_a = N - 2 \tag{14}$$

N is the total number of coils on the spring (Robert, 1985)

The solenoid power was evaluated from the under listed equation:

$$Power = \frac{Work}{Time} \tag{15}$$

ii. Construction

The machine was constructed using locally available materials and technology. The basic components of the machine include: chassis (produced from 2mm thick mild steel sheet, cut to 90mm by 70mm size using hacksaw); spring plunger guide, the material used was M6 stud, with a 3mm diameter hole cut at the longitudinal geometric centre of the stud; spring

plunger, 2.5mm mild steel wire cut to 100mm length using hacksaw; slider frame, 2.5 mm diameter mild steel wire cut to 148mm length and bend to 90° at a length of 70mm from both end using anvil; block, the material used was M6 stud, produced by drilling at a length of 5mm from one end a 3mm hole using drilling machine and spring stopper, produced in a similar way as the block.

iii. Testing and operation of the unrelaxed yarn automatic cutting machine

The unrelaxed yarn automatic cutting machine was designed to automatically cut twisted yarn that accumulates on the conveyor belt due to the flyer motor inertia after sudden power outage.

The constructed machine was tested by passing an un-relaxed yarn between the open blades of the machine and then connected to electrical supplies. The supply to the machine was subsequently switched off (to test the response of the

machine during power failure). In response, the machines' blades were fully closed, the yarn was cut off and after some delay the machine was re-opened and ready for the next cycle.

RESULTS AND DISCUSSION

The results of the experiments conducted and the design parameters evaluated are presented in this section.

Results

i. Determination of shear load of sample acrylic yeye yarn

The result of this test is shown in Table 1.

Table 1: Load to break the yarn

S/No	Yarn Breaking Load (N)
1	2.10
2	2.10
3	2.35

Average load required to break the yarn is 2.183 N

ii. Determination of limiting friction force between the blades of sample scissors

Table 2: load required to close the opened arms of the scissors

S/No	Load to open arms of the scissors (N)
1	1.6
2	1.6
3	1.6
Average Load:	1.6N

The length of the short and long arm of the scissors used is 25mm and 56mm respectively. Using principle of moment, the limiting friction force between the arms of the scissors was determined to be 3.58N (equation 2).

Design

The design parameters of the automatic yarn cutting machine evaluated using the equations presented in section 2.3 are shown in Table 3.

Table 3: Design parameters

Design Parameter	Value/Specification
Solenoid	
1 Power	4 W
2 Plunger length	15 mm
Helical Compression Spring	
1 Material	ASTM A231 steel wire
2 Spring rate (K)	595 N/m
3 Actual expected stress due to the operating force	895.2 Mpa
4 Number of active coils (N_a)	21
5 Solid length of the spring	13 mm
6 Free length of the spring	40 mm
7 Outside diameter of the spring	4.5 mm
8 Internal diameter of the spring	3.5 mm
9 Number of coils of the spring	24

Machine Performance Evaluation

$$\text{Efficiency } \eta_m = \frac{\text{Work done}}{\text{Work input}} \times 100\%$$

$$\frac{1.729}{4} \times 100\% = 43.2\%$$

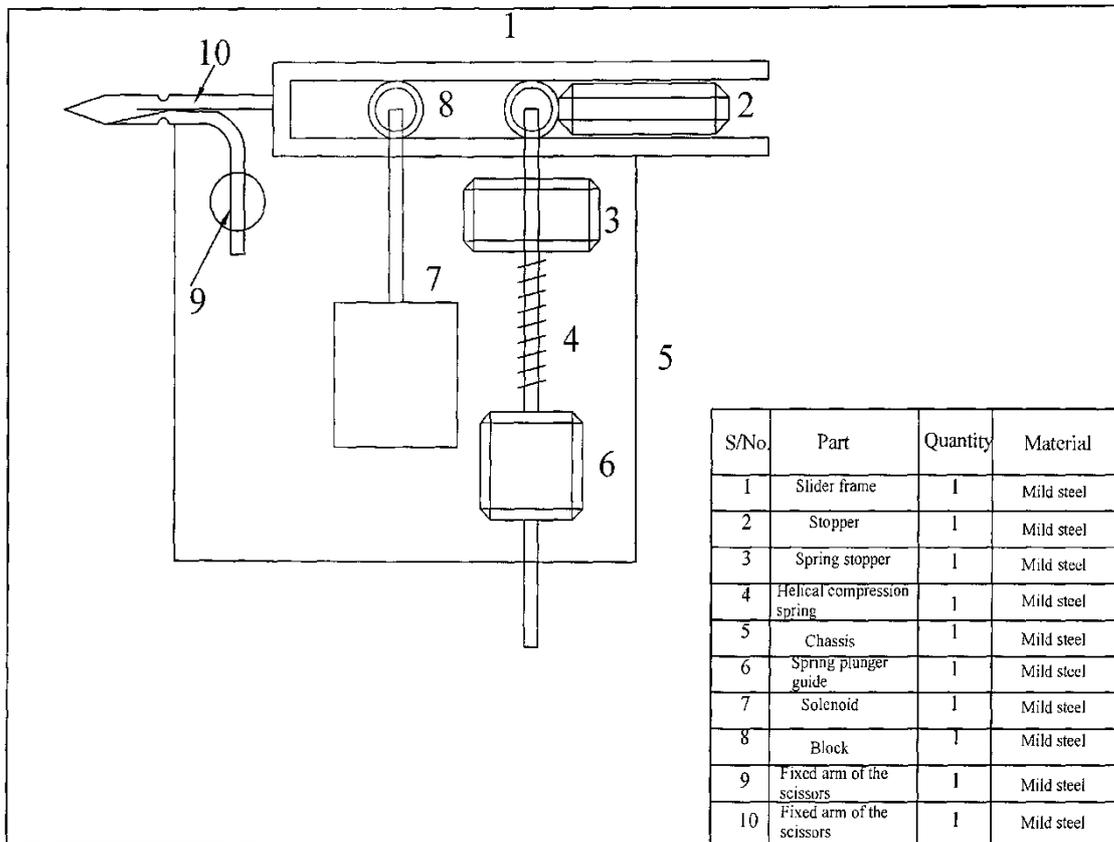


Fig 1: Schematic diagram of the designed un-relaxed yarn cutting machine costing

The total cost for the production of the automatic yarn cutting machine was fifteen thousand and eighty two naira only.
Discussion

Un-relaxed yarn cutting machine was developed through basic engineering design procedure. Experiments were conducted to determine the shear load of a sample acrylic yeye yarn and the limiting friction force between the blades of a sample scissors used for the design and construction of the machine. From the experiments conducted the average load required to break the yarn is 2.183N and the limiting friction force is 3.58N. Equations were used to evaluate parameters that are crucial to the design of the machine. The machine was constructed using locally available materials and technology. The constructed machine was tested for performance and the mechanical efficiency was evaluated to

be 43.2%. This is relatively low due to mechanical losses.

CONCLUSION

The results of the experiments conducted showed that the average load required to break the yarn is 2.183N and the limiting friction force is 3.58N. Un-relaxed yarn automatic cutting machine with a mechanical efficiency of 43.2% was successfully designed and constructed. The machine could be used to solve problems experienced due to power outages in yarn spinning industry.

RECOMMENDATION

The mechanical efficiency of the developed machine was found to be relatively low. Hence, it is recommended that the machine be improved to enhance its mechanical efficiency.

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