Design and Development of Fabric Cutting Machine for Handkerchief Manufacturers

Yash M. Zirale[1], Vijay A. Yelmar[2], Akash V. Salunkhe[3], Sumit S. Patil[4],
Prof. Bahubali Farande[5].
[1234](Department of Mechanical Engineering, KIT COEK, Kolhapur)
[5](Professor, Department of Mechanical Engineering, KIT COEK, Kolhapur)

Abstract:

In the textile industry during the manufacturing process, textile materials undergo different cutting operations. For these cutting operations, textile industries use either manual or automatic cutting methods, both having their own advantages and disadvantages. Manual cutting methods require more time, efficient manpower, and precession and accuracy, on the other hand automated machines are more concentrated over complex cuttings, aiding in high-speed mass production to achieve this they use pivotal mechanism which leads to an increase in costing. Thus small scale industries that practice simple cutting operations considering their earmark cannot afford these advanced high-priced machines and have to go for manual cutting methods. This project consists of designing a mechanism that will automate the feeding and cutting process. The project is more concentrated on designing and implementing a machine for handkerchief manufacturers which will after initial settings be able to achieve simple cutting operations on a large piece of fabric. The machine will have minimum investment cost and maintenance.

***Keywords* – Fabric cutting, mechanism, Productivity, Design and Development.**

I. INTRODUCTION

Clothing is one of the basic needs of human beings. [1] To meet this requirement textile industries are responsible, and they produce a wide range of textile products and for all diversity. During the textile manufacturing process, the cutting operation is the basic and essential operation. Fabric Cutting Machines are the equipment that performs simple and complex cutting operations on a large piece of fabric to get small pieces of the required size and shape. Initially, the cutting of fabric materials was performed manually using scissors and knife blades. After the industrial revolution and an increase in the demand for products instead of knife blades specially designed machines are used.

According to the operating process, and material the Cutting Machine can be classified into following types. [2]

- Manual.
  1. Hand Scissors and blades
- Semi- Automatic.
  2. Straight knife Cutting Machine.
  3. Round Knife Cutting Machine.
  4. Band Knife Cutting Machine.
  5. Die Cutting Machine.
  6. Notcher Machine.
  7. Drill Machine.
  8. Rib Cutting Machine.

- Automatic / Computerized.
  1. Laser Cutting Machine.
  2. Water Jet Cutting Machine.
  3. Computer controlled knife cutting
  4. Plasma Torch cutting Machine.

When it comes to small scale industries that require simple cutting of a large piece of fabric into small pieces especially like small scale handkerchief manufacturing they have to go for manual methods, as the automatic computer-based machines are costly. In such a situation the production is limited.

Considering the mentioned factors, designing a simple mechanism that can cut large fabric sheets into pieces in less time and with minimum cost will provide a solution to such problems. Automatic

Fabric feeding and cutting will increase productivity also accurate cutting and less maintenance will make the machine reliable.

II. MOTIVATION

The need for textile products is increasing day by day and textile industries are inclining towards more automation. The small scale industries such as handkerchief manufacturers cut the textile material in fixed dimensions as per their customer requirements. So they are required to simply cut it in pieces. In small scale industries, this is done manually with the help of scissors. There are machines available in the market but those are designed for complex cutting operations and are costly which is beyond their financial limit. As workload and demand are more the cutting process performed in the initial stages of production has to be completed in less time which is not possible because of limitations in manual methods. Due to these reasons, the production of such industries is limited.

This motivated us to develop a simple machine that can cut the large piece of fabric into required dimensional pieces. The mechanism will bring automation in the process and will eliminate the requirement of skilled workers and also will save some time required for the cutting process resulting in increased productivity.

III. PROBLEM DEFINITION

Manual textile cutting in small scale industries is time and effort consuming resulting in large cycle time and thus has low productivity and efficiency. So by designing & developing a Fabric Cutting Machine which will have minimum cycle time, and cost and ultimately will increase productivity of manufacturers especially those who manufacture handkerchiefs and related products.

IV. PRESENT STUDY

Table 1. Current Process

Sr no	Parameter	Manual Cutting
1	Time required	1 ½ hours
2	Labor quantity	1 skilled & 1 unskilled
3	Efficiency	70 %

Raw material: fabric sheet, 5.2 feet/157cm.

Finished product size: 52cm per piece (3 pieces)

Time required: 100min per roll.

Table2. Two hand process chart

Two hand process chart			
left hand		right hand	
○	lift the fabric roll	○	lift the fabric roll
⇨	place on the bar	⇨	place on the bar
○	pull the sheet	$\boxed{\bigcirc}$	cut the fabric with the help of scissors
○	turn over the side for cutting	○	turn over the side for cutting
○	pull the sheet	$\boxed{\bigcirc}$	cut the fabric with the help of scissors
○	load the cutted part again	○	load the cutted part again
○	pull the sheet	$\boxed{\bigcirc}$	cut the fabric with the help of scissors
$\boxed{\bigcirc}$	adjust the sheet	$\boxed{\bigcirc}$	complete the cutting process

Summary				
symbol	○	⇨	▭	
LH freq	7	1	1	
RH freq	7	1	4	
Summary after implementatio of Mechanism				
symbol	○	⇨	▭	
LH freq	2	1	1	
RH freq	3	1	1	

V. DESIGN CALCULATIONS

a) Design for power required

Calculations of Frictional Force:

As the rollers are covered the cotton there is a large friction between the two rollers. Also, the dynamic friction is always lesser in comparison therefore we will consider only static friction while designing the machine elements.

Considering friction factor as large as possible i.e. 1 for roller for static friction and 0.3 for PVC pipes. [3][4]

In below equations F1-F8 is the frictional forces.

F1 = 100×1 = 100N (1st pair of rollers)
F2' = 100×0.3 = 30N (PVC pipe 1)
F2 = 100+30= 130 N
F3'- frictional force due to cutting
F3' = l × t × s [5]

Where;
l – Length of fabric cut at the moment (1 mm) , t- Thickness of fabric (0.2mm)
s –shear strength of fabric

Also;
S = 0.8×tensile strength of fabric [5]
= 0.8×63.15
= 50.52N/mm2

As we are using 4 blades, cutting force become,
F3' = 4×1×0.3×50.52
= 60.62N
= 60N

F3' is the cutting force applied by blade which acts as a frictional force.

F3 = 60+130 = 190 N
F4' = 190×0.3= 57 N (PVC pipe 2)
F4 = 190+57 = 247 N
F5' = (247+100) × 1 (2nd pair of rollers)
= 347 N
F5 = 347 +247 = 594 N
F6' = 594×0.3 = 178.2 N (PVC pipe 3)
F6 = 178 +594 = 772 N
F7' = 772×0.3 =231.6 N (PVC pipe 4)
F7 = 772+231.6 =1003.6 N
F8' = (1003.6+100) × 1 (3rd pair of rollers)
= 1103.6 N
F8 = 1103.6+1003.6 = 2104.2 N

Total Force = F8=2104.2N

Torque Required = Force × Radius
= 2104.2 × 0.032 = 67.334Nm

This is the minimum torque required to overcome the friction and inertia of the system and extra torque will be required to drive the system.

1 HP motor gives the 745.7 Nm /s power at 1440 rpm.

ω =2πN/60 = (2π × 1440) / 60
= 151 rad /s

Power = torque × ω [6]

Hence, torque that 1 HP motor gives at 1440 rpm is = 745.7/151 = 4.9 Nm

Which is less than the required torque (<87.13 Nm). Hence, we have to reduce the rpm of motor to increase the torque output. To increase torque, we have used speed reduction gear box of ratio 20:1. The gear box gives the rpm = 1440/20 = 72 rpm

Then,
ω = 2πN/60 = (2π × 72) /60
= 7.5 rad /s

Hence, torque that 1 HP motor gives at 72 rpm is 745.7/7.5 = 99.42 Nm

So, by using gear box of reduction ratio 20:1 we will get torque 99 Nm (>87.13Nm: static friction) which is sufficient to movement of rollers. And also, we get required rpm 72.

b) Design of Shaft

Available data

- Shaft is connected to the frame through the integrated flange bearing with holes.
- Diameter of shaft (d) = 20 mm
- Length of the shaft (L) = 60 mm
- Maximum weight on most critical roller = 10 kg = 10×9.81 = 98.1 N
- We will be considering the shaft as Cantilever beam and load 98.1 N will be acting on its free end and its self-weight will be considered as UDL.
- RPM of the shaft(N) = 72 rpm
- Power (p) = 745.7 W

Assumptions:

- No axial force acts on shaft.
- Design is based on strength basis.
- We will be considering shaft as cantilever beam

Calculations:
Torque

$$P = \frac{2\pi NT}{60}$$

$$745.7 = \frac{2\pi \times 72 \times T}{60}$$

T = 99Nm

Moment
M = 98.1 ×0.060 + 1.212 × (0.060/2) + 2104.2 × 0.06 = 132.16 Nm

Since the general material is ductile, we will be using maximum shear stress theory

$$\frac{\pi}{16} \times d^3 \times f_{smax} = \sqrt{M^2 + T^2}$$

$$\frac{\pi}{16} \times 0.020^3 \times f_{smax} = \sqrt{132.16^2 + 99^2}$$

$$f_{smax} = 105.125 \ \frac{N}{mm^2}$$

For our application minimum Factor of Safety required is 2.5 [7]

Thus,

$$f_s = 105.125 \times 2.5 = 262.812 \ \frac{N}{mm^2}$$

According to the relation between Tensile yield strength and shear yield strength,

Shear yield Strength = 0.58×Tensile Yield Strength

$$TensileYeildStrength = \frac{ShearStress}{0.58}$$

$$TensileYeildStrength = \frac{262.812}{0.58} = 453.2 \ \frac{N}{mm^2}$$

According to the design data handbook, the mild steel of grade 45C8 (0.4-0.5 % C and 0.6-0.9 % Mn) is having tensile yield strength of 560 N/mm^2 [8] and it was available with us easily and relatively at low cost therefore the selected material is MS 45C8.

Actual FOS,

$$FOS = \frac{560 \times 0.58}{105.125}$$

$$FOS = 3$$

FOS is greater than the considered FOS and thus is acceptable for this application and thus Design is safe.

c) Design of Bearings

Data Available

- Each roller is about 10 kg weight. We will be considering the most critical bearing for the design i.e., for the shaft which is below the other shaft. It will be carrying the load of two rollers. Thus, force on bearings due to rollers= 10×9.81 = 98.1N Thus, force on one bearing = 98.1/2 = 49 N, Static Load on bearing = 49 N
- Considering the bearing is subjected to pure radial load (since the axial load will be transferred to the frame)
  Total Load = (weight of the components) + (Load due to other factors such as Human Load etc.)
  Total Static Load = 49 + 900 = 949 N
- Maximum rpm of the shaft = 100 rpm
- The expected life of the bearing (L10h) for industrial application for operating time of 8 hrs. /day = 20000 hr. [7]
- Inner diameter of the bearing = Diameter of the shaft = 20 mm

Assumptions: No axial load acts on the shaft. Thus, we will go with Single row deep groove ball bearing series.

Calculations:
Life of bearing with 90% reliability

$$L_{10} = \frac{60 \times N \times L_{10h}}{10^6}$$

$$= \frac{60 \times 100 \times 20000}{10^6}$$

L_{10} = 120 million revolutions.

Dynamic Load carrying capacity:
The maximum load which is coming on the bearing under dynamic condition is nothing but the tension of the cloth and static load.
C = 2722.88 + 949 = 3672.88 N

The necessary dynamic load carrying capacity of the bearing using static load.

$$C = P \times L_{10}^{\frac{1}{3}}$$

$$C = 950 \times 120^{\frac{1}{3}}$$

$$C = 4685.8\ N$$

i.e., minimum dynamic load for which bearing should be selected is 4685.8 N

For our convenience and simplification of the fabrication we chose to go with FL204.

According to the specification sheet provided by the manufacturers of the bearings, the bearing having nominal shaft diameter of 20 mm and having static load carrying capacity beyond 1000 N and dynamic load carrying capacity of 5000 N should be selected. [9] And for simpler fabrication, we chose to go with bearing **FL204.**

The chosen bearing has dynamic load carrying capacity of 11000 N and the actual maximum dynamic load in our application is 5000 N approximately.

d) Design of rollers
Considerations:

- Weight of the rollers = 10 kg each. Therefore, the maximum weight on the lower (most critical) roller = 10 kg Force acting on the roller = 10×9.81 = 98.1 N.
  Therefore, the intensity of UDL = (Weight) / (Length) = 98.1/1.6 = 61.32 N/m.
- Thickness of each rollers = 2 mm.
- Considering rollers as hollow shafts, we will be designing the rollers.
- Outer Diameter of the roller = 9 cm = 0.09 m.
- Thus, inner diameter of the roller = 0.09 – 2 × (0.002) = 0.086 m.
- Length of the roller = 160 cm = 1.6 m.
- Rpm of the roller = 72 rpm.
- Power of the motor = 1 HP = 745.7 W

Calculations:
Torque

$$P = \frac{2\pi NT}{60}$$

$$745.7 = \frac{2\pi \times 72 \times T}{60}$$

$$T = 99\ Nm$$

Maximum torque which will act on the roller is,
$$T = 99 + (2722.88 \times 0.045) = 221.53\ Nm$$

$$T = \frac{\pi}{16} \times {d_2}^3 \times (1 - K^4) \times f_s$$

Where,
K = (Inner Diameter)/ (Outer Diameter)

$$221.53 = \frac{\pi}{16} \times 0.09^3 \times (1 - (\frac{0.086}{0.09})^4) \times f_s$$

$$f_s = 9.3\ \frac{N}{mm^2}$$

Moment:
M = Load × (Length/2) = 98.1 × (1.6/2)
= 78.48 Nm

$$M = \frac{\pi}{32} \times {d_2}^3 \times (1 - K^4) \times f_b$$

$$78.48 = \frac{\pi}{32} \times 0.09^3 \times (1 - (\frac{0.086}{0.09})^4) \times f_b$$

$$f_b = 13.189\ \frac{N}{mm^2}$$

Using Maximum Shear Stress Theory. [7]

$$f_{smax} = \frac{1}{2} \times \sqrt{{f_b}^2 + 4 \times {f_s}^2}$$

$$f_{smax} = \frac{1}{2} \times \sqrt{13.189^2 + 4 \times 9.36^2}$$

$$f_{smax} = 11.45 \frac{N}{mm^2}$$

Thus, maximum shear stress produced in the roller is 11.45 N/mm^2.

By considering the factor of safety as '3',
Maximum shear stress = 3 × 11.45 = 34.35 N/mm^2.
According to the design data handbook and the references mentioned below, the 30C8 material is having the allowable shear stress 90 N/mm^2. [10]
Which less than the maximum shear stress produced in the roller and therefore the design of the roller is safe.

e) Selection of Belt Drive

Type: Open V-Belt Drive.

Reasons for selection of V belt [11]

- The force of friction between the surface of belt and V grooved pulley is high due to wedge action; this wedging action permits a smaller arc of contact which increases the pulling capacity of belt and consequently results in increase in power transmitting capacity.
- Short center distance.
- Smooth and quite action.
- In cross belt drive it has more power transmitting capacity but due to rubbing against itself while crossing it has low life, hence we decided to choose open drive.

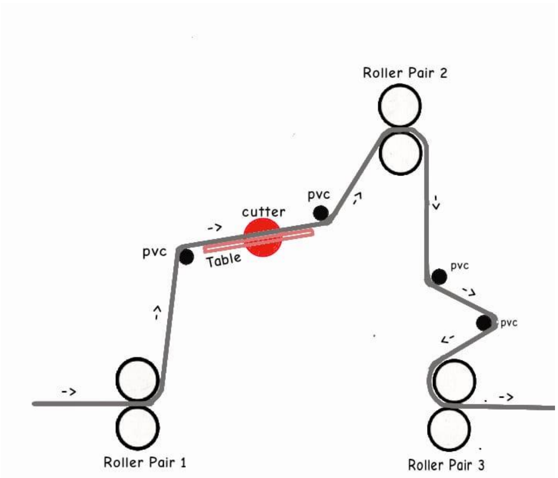

Fig1. Schematic side view

VI. PROPOSED MECHANISM

Fig2. Proposed mechanism

VII. CONCLUSION

Small scale textile factories find it difficult to invest in automated fabric cutting machines due to less financial support. Design and development of simple and cost effective automated cutting machines can help small scale textile factory owners to increase productivity. The mechanism helps in reducing stress and fatigue induced in workers while working manually. The mechanism provides flexibility to cut fabric sheets of various dimensions.

REFERENCES

[1] Denton, John A. "Society and the official world: a reintroduction to sociology". Dix Hills, N.Y: General Hall. p. 17. 1990.

[2] Vilumsone-Nemes, Ineta. "Industrial Cutting of Textile Materials", second edition, Woodhead Publishing, 2018.

[3] Dudley Fuller, 'Design Data Handbook on Coefficient of friction', Feb 1968.

[4] R. B. Belser and J.L. Taylor, 'Frictional Properties of Cotton Fibers', Grant No. 12-14-100-761(72).

[5] Meissner, Stephen, "Mechanics of a shear cutting process", Thesis. Rochester Institute of Technology, 1997.

[6] Parth shah, Chandresh Motak “Analysis & Optimization of Gearbox Efficiency- A Review” Volume 1 Issue 8 January 2015.
[7] V. B. Bhandari, ‘Design of Machine Elements’, McGraw Hill Companies, Third Edition, January 2011.
[8] “Design data handbook Indian Standard Designations of steels” IS: 1570 (Part I) – 1978 (Reaffirmed 1993)
[9] “Technical information” AST Bearings LLC, document no. Enb-04-0748 rev. B
[10] Design data handbook Carbon Steel Forgings for general engineering purposes IS 2004.
[11] Cammeda & C. Turin, ‘V-Belts Handbook’ Edition 2009.