Design, Development and Testing of Banana Fiber Extraction Machine

Prashant Shinde[1], Dr. Pramod Magade[2], Dr. Sushilkumar B. Magade[3]

[1]PG Student, Department of Mechanical Engineering, Zeal College of Engineering and Research, Pune, Maharashtra, India.

[2]Professor, Department of Mechanical Engineering, Zeal College of Engineering and Research, Pune, Maharashtra, India.

[3]Professor, Department of Mechanical Engineering, MIT AOE, Alandi, Pune, Maharashtra, India.

Article Info
Page Number: 1325-1339
Publication Issue:
Vol. 71 No. 4 (2022)

Article History
Article Received: 25 March 2022
Revised: 30 April 2022
Accepted: 15 June 2022
Publication: 19 August 2022

Abstract

Banana fibers are an excellent alternative to the synthetic materials that are often used in today's society, thus their use should be encouraged. Banana fibers are natural goods that are both biodegradable and favorable to the environment. There are around 5 million hectares dedicated to the production of bananas in India. The separation of natural fibers is a time-consuming process, and the quality of the end result might differ significantly depending on the extraction technique used. The banana fibre extraction machine is created and built in order to reduce the amount of time needed for the process while simultaneously improving the overall quality of the finished product. This device improved the quality of fiber by changing the design of blades. The sharpness of the blades was damaging fibers, hence, sharpness has been reduced by providing radius or chamfers to the blades. Also, distance between rollers decides the pressure applied onto the pseudo stem, which helps for the separation of fiber from waste of pseudo stem. As low as this distance is, we get good fiber. Also, the motor torque should be sufficient enough to rotate blades at optimum speed to crush pseudo stem.

Keywords: Banana Fibre, Extraction, Natural Fibre, Fiber Extraction Machine

1. Introduction

Jute fiber's environmental friendliness is mirrored in banana fiber's properties. It has a significant demand for export from a wide variety of nations, including Japan, Australia, Germany, and many more. The entire banana plant may be harvested for its supply of fibre. After the fruit has been harvested, the plant that produced it is discarded, leading to an increase in waste. Another issue is how to dispose of this plant in an appropriate manner. It is possible to collect a substantial amount of fibre by utilising a high-quality fibre extractor machine, which will lead to an increase in one's overall revenue. Because it has a high proportion of alpha cellulose and a relatively low amount of lignin, banana fibre is one of the best fibres available and has reasonably strong mechanical qualities. The Banana Fiber Extractor Machine is the first of its kind to be designed for the purpose of extracting fibre from the waste components of bananas, such as the stems, leaf stalks, and peduncles. The extraction of banana fibre, whether done manually or semi-mechanically, was laborious, time-consuming, and was known to cause harm to the fibre. It is a portable and low-cost gadget that was designed for the benefit of the agricultural community and the women's self-help organization. The cost of the Machine shifts depending on the market price of iron and steel. One hundred percent risk-free functioning of the equipment with lower overall maintenance expenses. Because of the machine's many applications, the governments of the respective states gave subsidies to purchase it. Both the Khadi Village Industries Board and the Horticulture Department are responsible for doling out the subsidiary. The machine has a production capacity of 25 kg in every eight hours. Natural fibre that is chemical free and superior in terms of colour and quality. Fiber is notable for being both lightweight and lustrous due to its inherent nature.

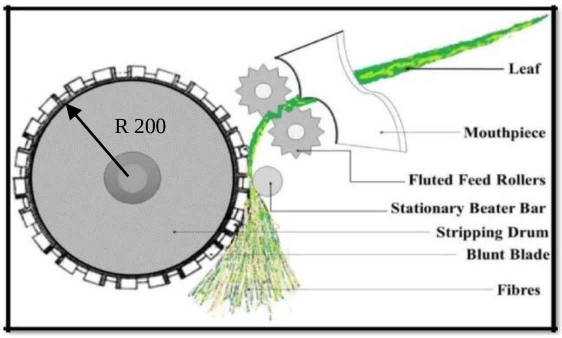

Fig. 1 Working principle of banana fiber extraction machine

2. Literature Survey

M. Ramesh, R. Bhoopathi, C. Deepa, 2014- this paper concluded that the conventional fiber or natural fibers have low strength than composite fibers. Composite fibers have high, low cost than these conventional fibers. So, by processing natural fibers we can have composite fibers. [1]

M.G.AruanEfendy ,K. L. Pickering and T. M. Le, 2015- this paper concluded that too much research has been done onto the mechanical properties of fibers and to improve it processing can be done and can be coneverted into compodite fibers to get desired properties.[2]

MoisésMorón , Zaida Ortega, Mario D. Monzón , Rubén Paz, Pere Badalló 2016- this paper concluded that fibers can be obtained by using mechanical machines of fiber extraction and consumption of natual fibers can be done. Processing can be done over natural fibers for increased desired properties and long length.[3]

Patrick Chester, **William Jordan,** 2017- this paper concluded that the internal bonding structure of the banana fiber can be studied, the effect of the processing to improve the tensile properties are positive, with peroxide treatment enhancement in the the tensile properties can be seen. [4]

Preethi P and Balakrishna Murthy G, 2013 this paper concluded that the farming of banana all over the world generates huge amount of biomass, which goes waste every year. Thousands of tons of fiber can be produced out of it.[5]

Dr. M. Sukumar, K Harini, K Ramya- 2018 this paper concluded that themain aim of the study is to produce nanofibers, from the banana peel and banana bract. It aims to study cellulose based polymers with acetyl and lauroyl upgradations.[6]

K AnandBabu, C G Prabhakar, Sreenivasreddy, S. Kataraki, 2021 Due to environmental problems, lot of study is getting done onto the natural fibers, even synthetic fibers replaced composite fibers into the market.[7]

L. Bangarappa, RaghvendraPai, Thomas Pinto 2021 Hybrid composites are used in various applications like automotive, industrial and other numerous applications.[8]

2.1 Research Gap:

Manual fiber extraction machines are too slow (200gm/person/day) from production point of view. As productivity is very low (200gm/person/day), hence, the fibers produced through manual machine are not cost effective or not competitive into the market i.e. Rs. 2500/- per kg. So, to have cost effective or cost efficient fibers, the production capacity per day of banana fiber extraction machine has to be increased. So, the cost of fiber will reduce (Currently the cost of banana fiber varies from Rs.150/- to Rs.200/- per kg).

The structure of banana fiber extraction machine should be rigid. The quality of fiber need to be improved by making changes in design to avoid damage of fiber.

2.2 Objectives

- To develop efficient and automated equipment for fiber extraction.
- To design and develop a suitable machine for multiple type fiber extraction.
- To avoid damage to the fibers.
- To improve productivity.

3. Design calculations and analysis

In this section, calculations of design are done by referring the various book, theories an standards. While doing this work, design finalization, dimensions of the parts and material selection are determined with reference to the function and loading conditions of the parts.

3.1 Pulley calculations

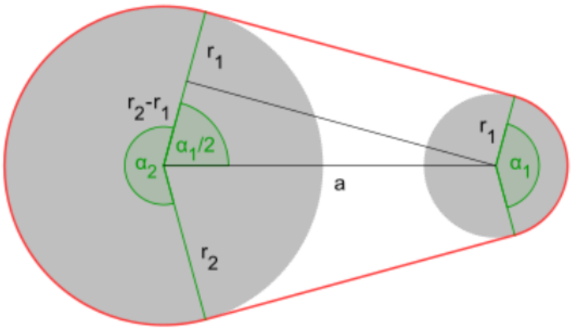

Fig. 2 Pulley Ratio Diagram

The diameter of the pulley will be decided as per the revolutions/min that we want of the blades.

d1 X n1=d2 X n2

Where,

d1= diameter of driven pulley

d2= diameter of driver pulley

n1=RPM of driven pulley

n2=RPM of driver pulley

Calculation for pulley on shaft (Driver Pulley):

40 X 300 = 150 X N1

N1= 40 X 300/150, N1=800 rpm

Calculation for driven pulley:

150 X 800 = 300 X N2, N2= 150 X 800/300, N2=400 rpm[3]

3.2 Bolt selection

Total load of the system(t)= motor vibration load + Rotary vibrations of blades + weight of system, etc.

Factor of safety= 1.5 times, New total load(T)= t X 1.5

Load carrying capacity of bolt M5= 160 kg, No. of bolts= T/b, So, we will use M5 bolts.

3.3 Design of frame

Frame design considering safety point of view 25x25x3 mm Square Hollow mild steel channel

b = 25 mm, d= 25 mm, t = 3 mm.

Let maximum load on frame =50 kg.

Force= W x g = 50 x 9.81= 490.5 N

Maximum Bending moment = force x perpendicular distance of Square Bar = 50 x 9.81 x 450

M = 220725 N-mm

As per the formula, $M / I = \sigma b / y$

Where,

M = Bending moment, I = Moment of Inertia about axis of bending; Ixx

y = Distance of the layer at which the bending stress is assumed (consider the maximum value of y)

E = Modulus of elasticity of beam

I = bd^3 /12= 25 x 25^3 / 12, I = 32552.08 mm^4

σb = My / I= 220725 x 12.5 / 32552.08, σb = 84.76N/mm^2

The allowable shear stress for material, σallow = Syt / fos

Where Syt = yield stress = 210 N/mm^2

And FOS = 2, So, σallow =105 MPa = 105 N/mm^2

Comparing above we get, σb<σallow i.e. 84.76 < 105 N/mm^2, So design is safe.

3.4 Welded Joint

Welded joint are the permanent joints with reliable strength, hence, to join sheetmetal parts and standard channels, welding is the best choice. Also, the leakage can be fully avoided by welded joints. Relief gaps at corners can be filled with welded joints.

Checking the strength of the welded joints,

Fillet weld between the side plate and the edge of stiffness plates,

The maximum load that the plate can carry is,

P = 0.707 x S x L x ft

Where,

S = factor of safety, L = contact length = 25mm

Shear load along with the friction is 50 kg = 490.5N

Hence, 490.5 = 0.707 x 3 x 25 x ft

Hence, ft = $\frac{490.5}{0.707 \text{ x } 3 \text{ x } 25}$, ft = 9.25 Mpa

As the calculated value of tensile load is very smaller than the permissible value of tensile load as ft=56 Mpa. Hence welded joint is safe.

3.5 Bearing calculations

UCP204-20MM has a combination of a cast iron pillow block housing with an anti-rotation device with self-alignment and a set screw locking chrome steel insert bearing with a slinger seal design. This specific unit is a standard duty pillow block bearing with a wide inner ring and two set screws and a cast iron unit with the standard base to center height with a grease fitting.

P=(X x V x Fr)+ (Y x Fa)

Where,

P= Equivalent Dynamic Load (N), X= Radial Load Constant, Fr = Radial Load (N)

Y= Axial Load Constant, Fa = Axial Load (N), X= 1, For Inner race Rotating, X= 1.2 , For Outer Race Rotating.

Fa = 0, Fr = 50Kg, = 50 x 9.81 = 490.5 N

P = (1 x 1 x 490.5) + 0, P = 490.5 N

Life of Bearing=L = $(\frac{C}{p})n$

Where, n= 3 Ball Bearing, n= $\frac{10}{3}$

L = $\frac{60 \times N \times LH}{10^6}$

LH = Consider 4000 Working Hours.

N = 1000 Number of revolution per minute =$\frac{60 \times 1000 \times 4000}{10^6}$

L = 240 …….. Putting Equation (1)

Dynamic Capacity (C) =240=($\frac{C}{490.5}$)3

C= 3048.1 N, C= 3.04 KN

3.6 Shaft calculations

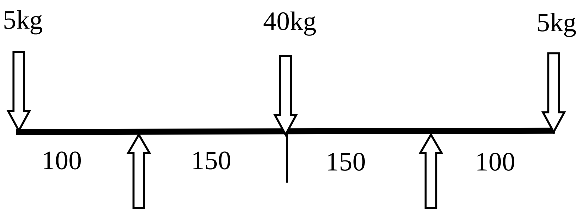

Fig. 3 shaft loading conditions

W= mg

Where, W= Weight (N), m= mass kg,

g = gravitational Acceleration (N/kg) = 50 Kg x 9.81 = 490.5 N

Bending Stress of Mild Steel Material is 100 Mpa

Maximum Bending Moment At point C

M= W x L = 40 x 9.81 x 150 = 58860N-mm

For Diameter of Shaft, M= $\frac{\pi}{32}$ x Bending Stress x d3, D=18.16

By Considering Standard Size= 20mm

3.7 Analysis

The developed machine can be validated for structural analysis using Finite Element Analysis Method. Following steps are taken to do the structural analysis of banana extraction machine so further utilised for extraction purpose.

3.7.1 Modelling

Cad model is prepared by using CATIA software. The workbench used to make the cad model is sheet metal as most of the parts are sheet metal, brackets, channels. Purchase parts are downloaded from the site www.mcmaster.com. Also, commands like base flange, flange, relief are used.

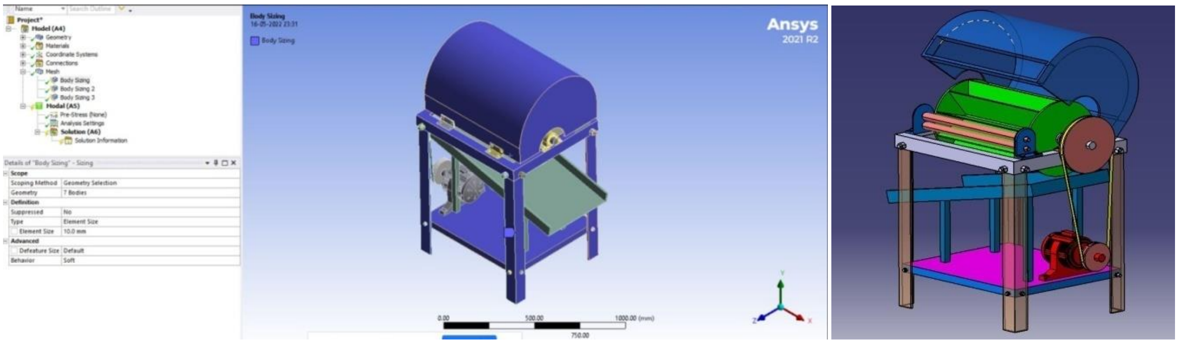

Figure 4: Cad model Developed in Catia

3.7.2. Meshing

After Model developed in design model, it is taken for meshing. A programme-controlled meshing is adopted. In meshing surface area covered is 6860.6 mm^2, nodes are 1380664 and elements are 851203. The type of mesh elements used are Tet10, Hex20 and Wed15. The meshing is completed and further this mesh component used for structural analysis purpose.

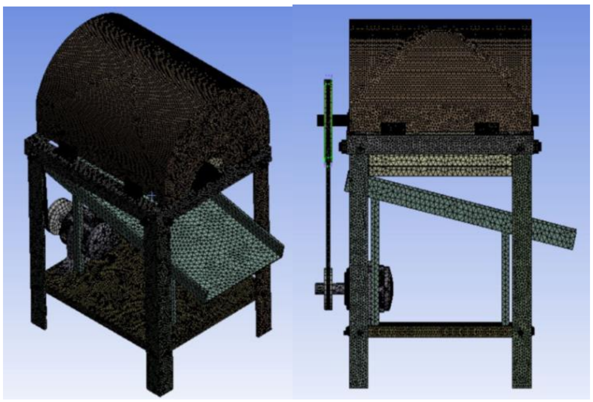

Figure 5 Meshing of Developed Model

Ansys Results

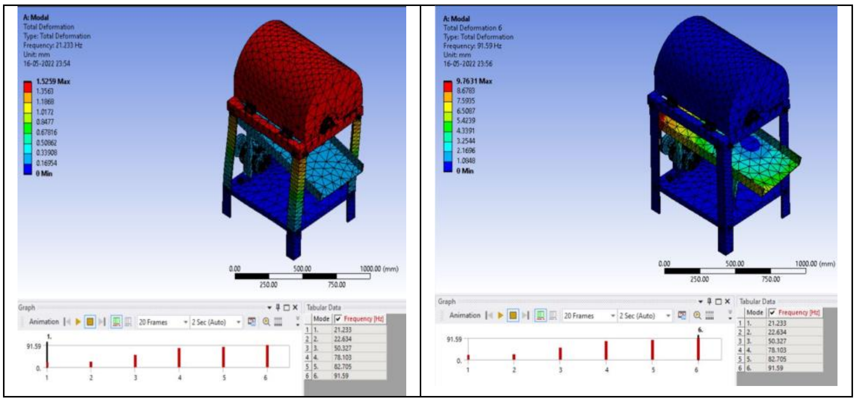

Figure 6 Deformation results for frequency

The total deformation for the developed banana extraction machine is calculated for different frequencies and it is shown in figure 7. The data shows the linear relationship between frequency and deformation. As frequency increases deformation increases. Frequency parameter is considered because the motor is used for the rotation of blades, due to which the vibration of assembly may occur and because of which instability of the structure may occur, hence, frequency and the deformation with respect to it is considered.

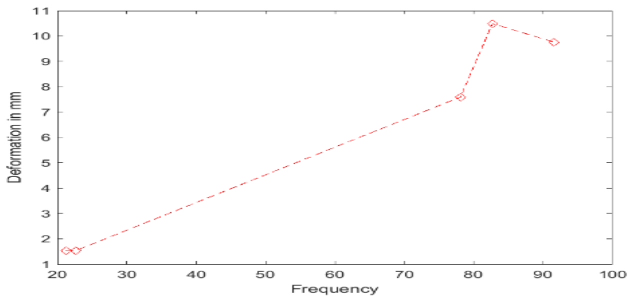

Figure 7 Ansys results Frequency vs Deformation

The outline of this project is to provide a rigid structure of the machine, so that the there will not be vibrations in the machine due to motor. Also, the center of gravity of the machine is at proper location. As the machine is bolted at bottom, hence provides extra strength and stable structure of the machine.

4. Experiment Work

4.1 Fabrication

1. By using appropriate manufacturing processes, various components are produced.

2. With respect to drawing, parts are produced.

3. Trials are taken to validate the results.

4.2 Experimental Investigations

Machine will be tested by taking actual trials by using various samples of pseudo stem. So, this testing will validate the results and will include actual site testing.

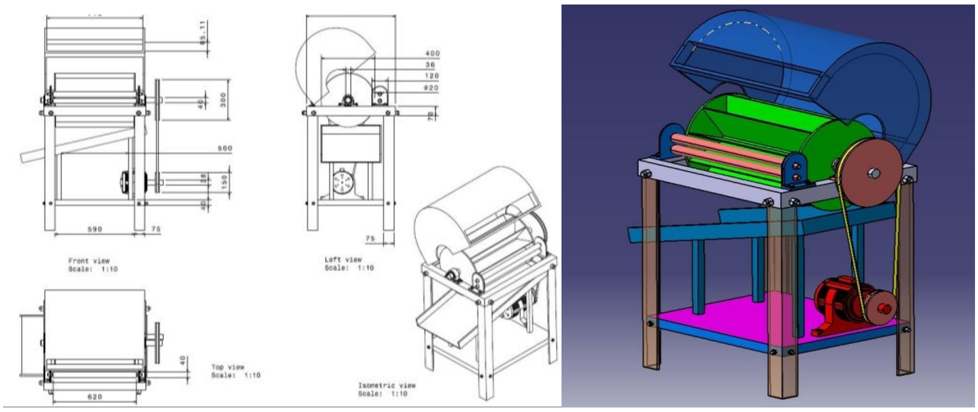

Figure 8: Drawing of banana fiber extraction machine

The raw material i.e. plant stems/stalks/leaves are fed to the blade drum as input. The high-speed rotating blade drum and fixed blades crushes the raw material and separation of fibers and waste. Suitable settings are maintained in the machine to retain the essential properties of the extracted fibers.

5. Machine Testing

To test and validate the working of developed mechanism for banana fiber extraction machine, to take practical operating trials at different clearance conditions between the rollers. Also, to gather the feedbacks and enhancement requests in developed model.

5.1 Experimental Conditions and testing procedure

Testing of the banana fiber extraction machine is done by arranging banana psedostem as raw material to produce fiber. Raw material is arranged from the nearby market of market yard, Gultekdi. The purpose the test is to prove that, by adjusting clearances between rollers, we can have tremendous results in the quality of fibers. Also, as the blades sharpness has reduced by providing chamfers to the blades, avoids damage to banana fibers.

Pseudo stem has been processed as per Nepalese technique before the test, so that we can have actual fiber as per market requirement before finishing touches.

1. Feed system adjusted with clearances like 6mm, 5mm & 4mm between rollers.
2. Motor starts with approximately 500 rpm.
3. Pseudo stem is fed between the rollers.
4. Above steps are repeated at varying speeds of 550 rpm, 600 rpm & 640 rpm.
5. Values are taken by varying clearance between rollers and varying rotating speeds.

Technical Specifications of the Machine:

1. Speed of the machine: 3000 rpm
2. Motor used: 3phase 2hp AC Motor & Electric Starter
3. Extractor rollers used: roller with diameter of mm
4. Other rollers used: steel roller with diameter of 40 mm
5. Power supply: 240 volts AC supply
6. Squeezing mechanism: 2 Rollers made of 40 mm diameter
7. Drive system: belt drive system
8. Base frame: made out of mild steel

5.2 Experimental Results for samples

Clearance between rollers	Stem prior to processing (kg)	Stem later processing (kg)	% fiber yield	Drum rpm
6mm	0.4	0.30	15	640
	0.25	0.17	13	640
	0.5	0.32	15.5	640
	0.3	0.18	13.25	640

Table 1: Results of Samples with 6mm clearance

ISSN: 2094-0343
2326-9865

Clearance between rollers	Stem prior to processing (kg)	Stem later processing (kg)	% fiber yield	Drum rpm
5mm	0.4	0.25	17	600
	0.25	0.10	15	600
	0.5	0.28	17.5	600
	0.3	0.12	15.25	600

Table 2: Results of Samples with 5mm clearance

Clearance between rollers	Stem prior to processing (kg)	Stem later processing (kg)	% fiber yield	Drum rpm
4mm	0.4	0.22	20.5	550
	0.25	0.9	17	550
	0.5	0.25	21	550
	0.3	0.11	18.5	550

Table 3: Results of Samples with 4mm clearance

Clearance between rollers	Stem prior to processing (kg)	Stem later processing (kg)	% fiber yield	Drum rpm
3mm	0.4	0.20	25	550
	0.25	0.9	19	550
	0.5	0.18	27	550
	0.3	0.10	20	550

Table 4: Results of Samples with 3mm clearance

6. Results and discussion:

A summary of the results shown in the above Table 1, 2, 3 & 4.

Samples were tested at different speeds like 500 rpm above & even at lower speeds, but it is observed that at lower speeds, fibers are not getting separated properly. Hence, the speed of rotation should be more than 500 rpm.

Also, as the distance or clearance between rollers increases, the waste increases and the fibers separation is improper. The fiber obtained with more clearance between rollers, have lot of unnecessary wastes.

Length of the stem	Thickness of the stem	Motor Speed	Distance of two rollers	Fiber recovery rate
45.72 cm	1 cm	2800 rpm	8 mm	No fiber recovered.
45.72 cm	1 cm	2800 rpm	7.62 mm	0.01% - 0.05%
45.72 cm	1 cm	2800 rpm	7.112 mm	0.1% - 0.3%

Table 4: Compare with IJRTE journal Design and development of banana fiber paper

Also performed tensile tests onto the samples of pseudo stems of banana & we came to know that the pressure to be applied onto the pseudo stem for the separation of waste from fibers, is been applied when the distance between rollers is 4mm or less.

As the blades used before, were sharp, hence, the damage of the fiberswere too high. When we provided radius or chamfers onto the blades to reduce sharpness of blades and increase bluntness, then the damage of fibers reduced.

As shown in table 4 taken from IJRTE journal of Design and development of banana fiber paper, it can be seen that distance between rollers when reduced gives sufficient pressure onto the pseudo stem for the separation of waste from fiber. In this journal, only motor torque and distance between rollers is considered, whereas, along with motor power, distance between rollers, extra parameters like design changes in blade to avoid damage to fiber, cost of machine, manufacturing process, cost and productivity of fibers has also been considered. Hence, it is validated that the results are more reliable and satisfying compared to previous research done onto the area.

These are some of the observations from the results.

Figure 9:sample testing on prototype

Conclusions

As a conclusion of this project, all the gaps which has been considered, have been taken care of. Automated machine is designed and developed, which has improved productivity of the machine. Also, the fiber produced is competitive into the market with respect to quality & cost. The production of fiber produced per day increased 20-25 times. Machine is also cost effective. The gap between the rollers should be 3-4mm. Also, the average speed of rotation of blade should be 550 rpm. Even the power of motor should be higher to have sufficient torque while crushing pseudo stem.

Scope for future work:

1. It can be modified for other fibres such as bamboo.
2. Microprocessor controllers can be used to vary the speed.
3. Feed sensors can be used to vary the gap between feed rollers according to the fibre thickness.

Reference

1. P.K. Bharti. “recent methods for optimization of plastic injection molding process –a retrospective and literature review”. International Journal of Engineering Science and Technology Vol. 2(9), 2010, 4540-4554
2. D. Mathivanan& N. S. Parthasarathy. “Sink-mark minimization in injection molding through response surface regression modeling and genetic algorithm”. Int J AdvManufTechnol (2009) 45:867–874
3. Vijaykumar Vilas Andhalkar, Dr. S. R. Dulange. “Injection molding methods design, optimization, simulation of plastic flow reducer part by mold flow analysis” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056,(2017)
4. HariyantoGunawan and WillyantoAnggono. “improving quality of injection mold using moldflow software simulation case study: new design plastic cup” proceeding of international seminar on product design and development 2006
5. P. P. Shinde, S. S. Patil, S. S. Kulkarni, “Design and Development of Plastic Injection Mold for Auto Component”, International Journal of Advanced Engineering Research and Studies E-ISSN2249-8974.H.
6. J. Ganeshkar, R B Patil, “plastic Injection Mold Design for An Automotive Component “air Vent Bezel” Through Mold Flow Analysis for Design Enhancement” International

Journal of Innovation in Engineering, Research and Technology [IJIERT] ICITDCEME'15 Conference Proceedings ISSN No - 2394-3696.

7. S.M. Nasir, K.A. Ismail, Z. Shayfull, M.A. Md. Derus. "Warpage Improvement of Thick Component Using Taguchi Optimization Method for Single and Double Gates in Injection Molding Process", Australian journal of basic and applied sciences,7(5), ISSN 1991- 8178, 2013, 205-212.
8. A.M. Gwebu, L. Nyanga, S.T. Nyadongo, A.F. Vander Merwe, S Mhlanga, "Effect of mould temperature on the filling behavior of molten resin in plastic injection moulding of HDPE", SAIIE 26, 2014
9. P. Sanap, H M Dharmadhikari, and A J Keche,"Optimization of Plastic Moulding by ReducingWarpage With the Application of TaguchiOptimization Technique & Addition of Ribs inWashing Machine Wash Lid Component", IOSRJournal of Mechanical and Civil Engineering(IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 5 Ver. I.
10. M. Vishnuvarthanan, Rajesh Panda and S. Ilangovan. "Optimization of Injection Molding Cycle Time Using Moldflow Analysis". Middle-East Journal of Scientific Research 13 (7): 944-946, 2013 ISSN 1990-9233
11. Ms. G ThasleemaNasreen and Mr. N Praveen Kumar. "Optimization of a Composite Drive Shaft by Minimizaton of Sink Mark Defects in Injection Moulding Process". IJTSRDISSN No: 2456-6470
12. Corbière-Nicollier T., B. G. Laban, L. Lundquist, Y. Leterrier, J. -A. E. Månson, and O. Jolliet,(2001), Life Cycle Assessment of Biofibers Replacing Glas
13. SuphanYangyuenDesign and Construction for Extraction Fiber Machine from Banana Stem Engng.J.CMU (2012) 19 (3), 34-41