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Automatic waste Plastic Recycle Machine Integrated with Extrusion Hopper Mechanism

Abebe Mengistu Alemayehu , A HarshaVardhan Reddy, Nehemiah Mengistu, Lemi Negera Woyessa , P.Vijay

Abstract*: Dumping of waste plastic, which are non-biodegradable causes serious environmental problems. Not only do they take up huge amount of space in dumping landfills but also being a non-renewable resource, it faces depletion. Hence, it is very essential wherever possible to reduce these waste plastics means of recycling. In addition, the increasing trends of plastics in varied applications drives for more solutions for reuse of waste plastics. The existing recycling machines, which are currently in operation, are expensive and are operational only for large-scale industries. In addition, shredder and extrusion work separately but on this study shredder and extrusion are integrated to perform the given task simultaneously including mold. All section of the machine operates based on timing. This present work hence focuses on designing a plastic recycle machine for small-scale applications by incorporating an extrusion hopper mechanism. Various machines parts and assembly of hopper, shredder, extruder, heating-coil, molder, and frame are designed and analyzed using CATIA, ANSIS and FESTO. Detail analysis of the machine becomes an efficiency of 80%, having a capacity of delivering up to 20.4 kg of finished plastic blocks per hour. The working capacity of the machine ware almost three full cycle per minutes which gave the production rate of 180 products per hour.

***Keywords* : ANSIS , CATIA, Extrusion Process, Recycle Machine,Waste Plastic.**

I. INTRODUCTION

The world consumes more and more plastics. Plastics are materials with many different applications. The use of plastics often saves energy, but it causes thus climate emissions. More recycling of plastics reduces the climate gas emissions. The annual report for the Ethiopian fiscal year 2014-2015 prepared by Solid Waste Management Agency revealed that awareness creating among the society was one of the functions performed in collaboration with different Media outlets such as Ethiopian Television, local FM radio stations and newspapers.

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Accordingly, 186% of respondents claimed to get the information from Media which usually transmit interviews, complaints from residents .51%respond as they learned about the situation from fliers distributed by the Woreda Administration. Billboards and posters erected along roadsides also contributed in alerting 10% of the respondents. [2]

1.1. Background: There are two major categories of plastics include thermoplastics and thermosets. These are easily recyclable into other products. These thermoplastics include polyethylene, low and high density (LDPE, HDPE) polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), polyethylene terephthalate (PET) etc. Thermoset plastics contain alkyd, epoxy, ester, and melamine formaldehyde, polyurethane and so on, which are cross linked on curing and will not soften with heat to allow these to be formed into different shapes. [3]

Figure 1 waste plastic around revers (takes, 9 February)

Figure 2. Hauling the waste by truck

II. LITERATURE REVIEW

Home wastage or municipal Waste of materials converting into fuel in various countries. A research [4] done on coconut waste. From Previous done researches and projects, we take the relevant information to design and manufacture appropriate plastic recycling machine for our country.

Figure 4. Model of Plastic Recycling Machine

Figure 5. Fabricated view of machine

III. DESIGN ANALYSIS; MATERIAL AND METHOD

Method

Mechanism synthesis

Develop a mechanism that can perform the required tasks easily.

Data collecting

Collecting primary and secondary data that are relevant for the project. Primary data are collected by Measurement of waste plastic size directly, interviewing: waste management sector, climate change and environmental conservation sector, agriculture departments in DBU and calling phone for waste management and environmental conservation ministry of Ethiopia and secondary data are collected from different literatures from the internet and books.

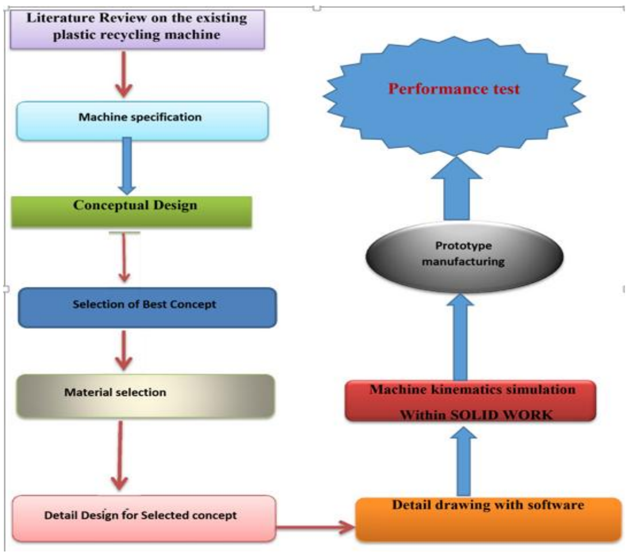

Figure 6. Block diagram of methodology

Design

Conceptual design of different alternative mechanisms, Detail design of components, Elements outline design selection of best elements and the best mechanisms was being made. In addition to this we perform analytical and software analysis to part design

Prototype manufacturing

Manufacturing the mechanical parts and assembling to form waste plastic recycling machine.

Field testing

The machine must be test for performance.

Concept generation and component selection

Plastic recycling machine comprise a lot of systems such as shredder system, plastic conveying system, feeding system, extruding system, molding system and final product conveying system. These each system have different mechanism. The best mechanism for each system is selected as bellow according to their complexity, ease of fabrication and simplicity by considering different selection parameters including maintainability, availability, cost, weight, efficiency and so on.

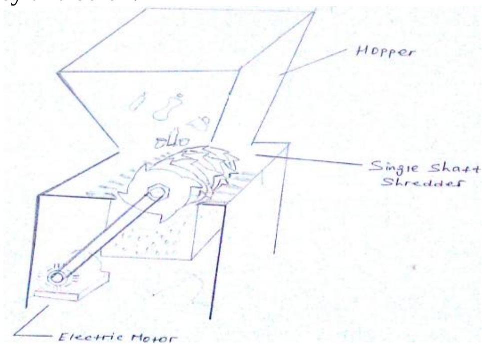

Figure 7. Single shaft shredder

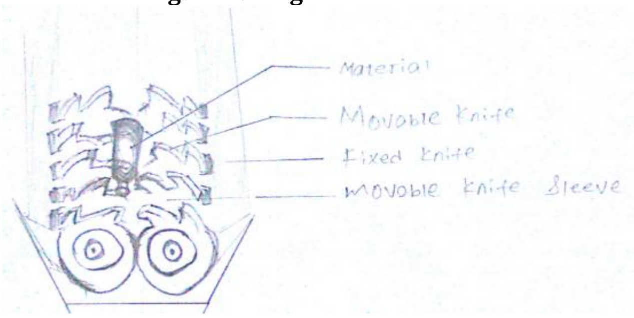

Figure 8. Double shaft shredder

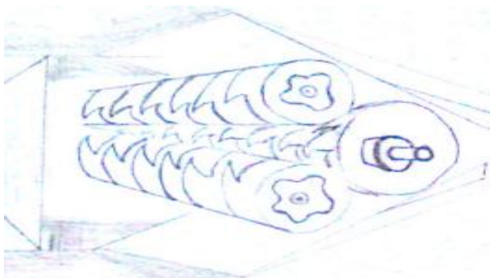

Figure 9. Triple shaft

Speed of the belt on the driven pulley to determine the speed of belt on the driven pulley,

Table 1. Shaft selecting table

Criteria	Single shaft %	Double shaft %	Triple shaft %
Availability15%	13	13	13
Weight15%	14	9	10
Load capacity25%	20	22	13
maintainability 10%	9	7	5
Effectiveness 10%	10	8	7
Cost25%	24	17	15
Total100%	90	76	63

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According to the above data who's prepared by matrix single shaft plastic shredder is selected for this system. It will have main components fixed bleed, rotary bleed, rotary bleed base, rotary bleed guide, rotary bleed head with frame.

i. *Design of hopper*

Volume of the hopper = ($^1/_3$ [A_1 + A_2 +√(A1+A2)] ✕ h2)+(A1xh1)

Where, A_1= Area of top pyramidal section

A_2= Area of bottom base

h1= Height of hopper for rectangular section only

H2,= Height of hopper for pyramidal section only

A1=60X60MM=3600MM2

A2=20X20MM=400MM2

H1=60MM

H2=80MM

V=(60/3[3600+400+√(3600+400)]+(3600x80))

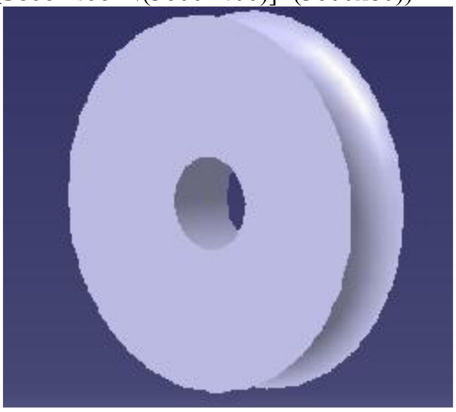


Figure.10. Pulley

Depending on the table, HSS is selected for waste plastic cutting blade.

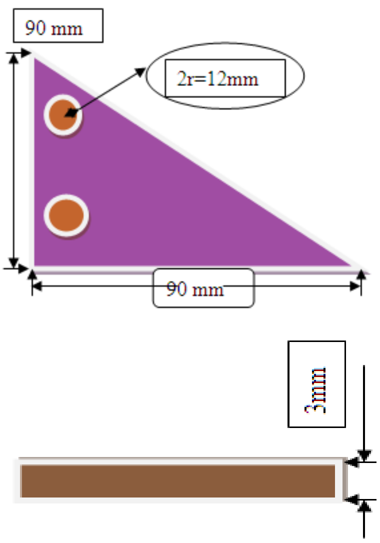


Figure.11. Front and End View of the Cutting Blade

Torque T, produced by the shaft **Invalid source specified.**

Torque = Fr (1)

Where:

F = Force required by the shaft to turn the polythene

r = Distance of the blade end from the center of the shaft

Angular Velocity, $\omega = {}^{2\Pi n}/60$ (2)

Where:

N = Speed of the motor in revolution per second

Linear Velocity, v = ωr (3)

v = $^{2\pi Nr/60}$ (4)

But, From Newton's Second Law of Motion:

F=mv/t (5)

Where:

m = mass of the shaft in Kilogram

t = time in second

Substituting (4) into (5) gives:

F =2πmNr/60

For one second, the force required will be:

F =2πmNr/60 (6)

Substituting (6) into (2) gives:

$2\pi m N r^2$ Torque, T of the Shaft = F =$2\pi m N r^2/60$ (7)

T = (2 × π × 10 × 1067 × 0.12)/60=11.17 Nm

T = 11.17 Nm

Power required to overcome the torque and to rotate the

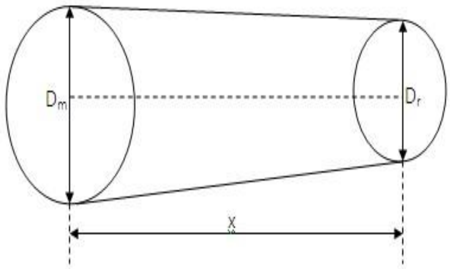


Figure12. Open belt drive

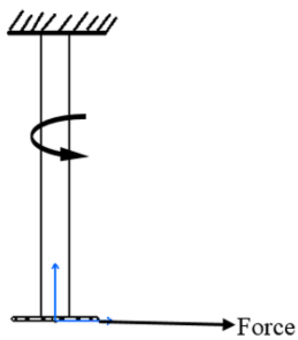
Table 2 Characteristics of roller chains according to IS: 2403 — 1991 [11]

ISO chain member	Weight of chain (kg/m)	Breaking load minimum (Kn)		
		Simple	Duplex	Triplex
05B	0.18	4.4	7.8	11.1
06B	0.39	8.9	16.9	24.9

Table 3. power rating (in kW) of simple roller chain.

Speed of smaller sprocket or pinion (rpm)	Power (kW)				
	06B	08B	10B	12B	16B
100	0.25	0.64	1.18	2.01	4.83
200	0.47	1.18	2.19	3.75	8.94
300	0.61	1.70	3.15	5.43	13.06
500	1.09	2.72	5.01	8.53	20.57
700	1.48	3.66	6.71	11.63	27.73
1000	2.03	5.09	8.97	15.65	34.89
1400	2.73	6.81	11.67	18.15	38.47
1800	3.44	8.10	13.03	19.85	-
2000	3.80	8.67	13.49	20.57	-

Note: The r p.m. of the sprocket reduces as the chain pitch increases for a given number of teeth.



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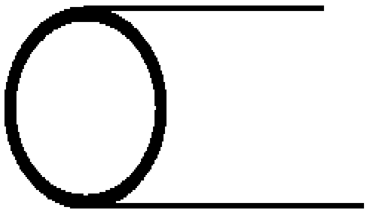

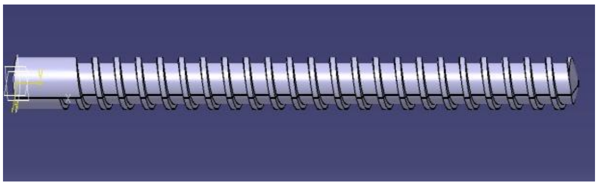

Fig-13 screw drawn by CATIA software

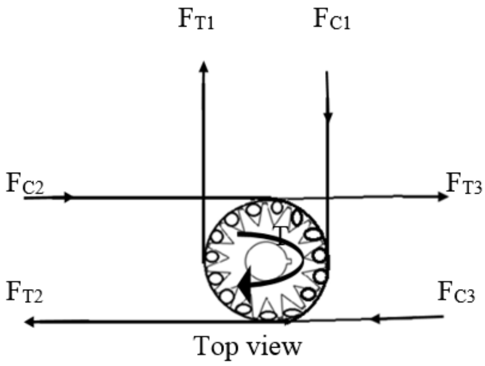

Figure.14. Solid and hallow shafts

Product design

In this project the product is sprocket gear, each dimension is taken from real its usage area.

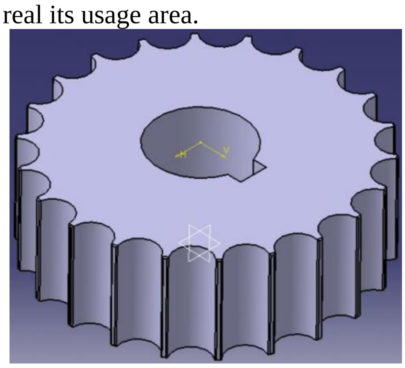

Figure 15. Sprocket gear

Area A =area of whole-area of hole-area of key way-area of pitch

$A = (2\pi x64^2 + 2\pi x64x40) - (2\pi x20^2 + 2\pi x20x40) - 6x40 - \frac{1}{2} x22\ (2\pi x8^2 + 2\pi x8x40$

$= 31628.3xmm2$

$= 3.1628x10 - 2m2$

Volume of part = volume of the whole – volume hole-volume of key way-volume of pitch

$V = \pi x642x40 - \pi x202x40 - 40x12x6 - (\frac{2x\pi x8^2x40}{2})$

$= 373105.8mm3$

$= 3.731058x10 - 4m3$

The total part volume is $2x3.731058x10^{-4}m^3 = 7.462x10^{-4}m^3$ since the machine produce two parts at a time.

Mass of part is calculated using density its volume

Mass (M) = density*volume=1420 $kg/m^3 x\ 7.462x10^{-4}m^3 = 1.06kg$

The shot weight of the machine is **1.06kg**

Table 2.power low parameters for some common plastics

Polymer	m(pa-s)^n	N	T(°C)	Thermal conductivity (W/m .k)
High density PE	2.00 x 10^4	0.41	180	0.23
Low density PE	6.00 x 10^3	0.39	160	0.19
PP	7.50 x 10^3	0.38	200	0.31
Acetal	8.25 x 10^4	0.197	300	0.23

$$\Delta P1 = \frac{Kr}{10^4(1-n)}\left[\frac{360xQ(1+2n)}{Ngx360x4\pi xnxr2x(b)^2}\right]^n \cdot (\frac{r2}{b})$$

Where K_r *is shape factor*

$K_r = 3.05x10^4\ cm^5/Ns$

n = power low exponent =0.197 from the above table4

Θ=melt flow angle =360°

r_2 = Radius of the disc=120mm

N_g = number of gates=2

b = Half thickness of the disc=1.05mm

Q = constant injection rate= $\mathbf{1.293x10^{-3}m^3/s}$

Then the pressure drop is $= 206.6$ bar

The dimension less τ fill time is defined as

$$\Delta P1 = \frac{3.05x10^4}{10^4(1-0.197)}\left[\frac{360x1293(1+0.197)}{2x360x4\pi x0.197x12x(0.105)^2}\right]^{0.197} \cdot (\frac{12}{0.105})$$

The dimension less τ fill time is defined as

$$\tau = \frac{V.a}{Q.b^2}$$

Where $V = part\ volume$

$= 7.462x10^{-4}m^3$

$= 746.2cm^3$

a =Thermal diffusivity of the polymer

$= 0.09mm^2/s$

The Brinkman number is given by

Where

λ = Thermal conductivity of the melt=0.23(W/m.k) from table-6

Inlet melt temperature T_M=216+273=489k

Mold temperature $T_W = 93 + 273 = 366k$

N=2 nuber of gate

Then

$$Br = \frac{(0.105)^2x3.05x10^4}{10^4x0.23x(489-366)} \cdot \left(\frac{1293}{2x360x2\pi x0.105^2 12}\right)^{1+0.197} = 3.44$$

Then the actual pressure drop through mold is calculated as follow

$\ln[\Delta P/\Delta P_1] = 0.337 + 4.7\tau - 0.093Br - 2.6\tau.\ Br$

$= 0.337 + 4.7x0.0471 - 0.093x3.44 - 2.6x0.0471x3.44 = -0.1828$

By making exponent in both side.

$\Delta P = \Delta P_1 x0.833 = 206.6barx0.833 = 172.08bar$

Therefore, the actual pressure drop is less then injection pressure, then design is safe.

$$Br = \frac{b^2.k_r}{10^4.\lambda.(T_M - T_W)} \cdot \left(\frac{Q.360}{N.\theta.2\pi.b^2r_2}\right)^{1+n}$$

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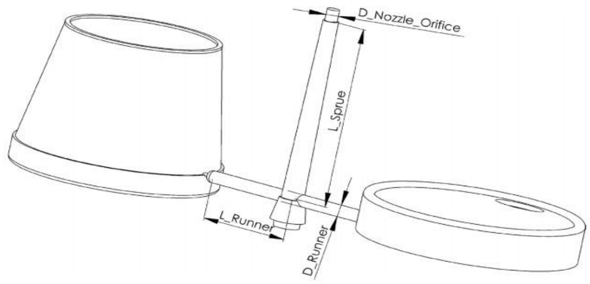

Figure.16. shows feed system

i. *Nozzle design:*

The main nozzle body extends from the barrel end cap to the sprue the figure bellow shows the nozzle.

The nozzle starting diameter is equal to barrel diameter of plunger=80mm

The nozzle orifice diameter of =12mm

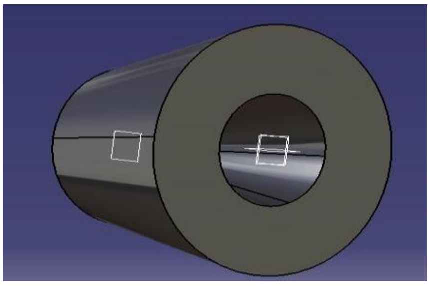

Figure 17. sprue nozzle

As we see from the above picture the shape of the nozzle is frustum cone, therefore the volume of nozzle is

$V_N = \pi\_\ h(R^2 + r^2 + Rxr)3$

Where $VN = nozzle\ volume h$ = nozzle length taking the inclination of orifice 25°. h is calculated as

$$h = \frac{[\frac{80-12}{2}]}{\tan(25^0)} = 73mm$$

R =radius of plunger r = radius of orifice

$$V_N = \frac{\pi}{3}x73(40^2 + 6^2 + 40 + 6) = 11782.55mm^3 = 1.178x10^{-4}m^3$$

section with a radius of 35 mm and a length of 60 mm. The pressure drop is then

$$\Delta Pnozzle = \frac{2x\eta L}{R}\left[\frac{(3+\frac{1}{n})Q}{\pi R^3}\right]^n$$

Where ΔP_{nozzle} =pressure drop through nozzle

n =*power low endix*

R = avrage radius of nozzle

Q = flow rate

L= length of nozzle

$$\Delta Pnozzle = \frac{2x745x0.06}{0.035}\left[\frac{\left(3+\frac{1}{0.197}\right)x1.293x10^{-3}}{\pi 0.035^3}\right]^{0.197}$$

$= 6018.53Pa \approx 0.6018bar$

i. *Sprue design:*

it one melt polymer feed system. Its inlet diameter is equal to nozzle orifice diameter i.e. 12mm

The ratio of inlet diameter to out let diameter of sprue is 1.5

Therefore $\frac{12}{d_0} = 1.5,\ d_0 = \frac{12}{1.5} = 8mm$

Length of sprue L=30mm

Volume of sprue

$$V_{sprue} = \frac{\pi}{3}xL(R^2 + r^2 + Rr)$$

$=(\pi/3)\ x0.03((0.006)^2 + (0.004)^2 + 0.006x0.004)$

$= 1.2566x10^{-6}m^3 3$

Estimating pressure drop through sprue is important. It can be estimated directly without calculation of the shear rate as

$$\Delta Psprue = \frac{2x\eta L}{R}\left[\frac{(3+\frac{1}{n})Q}{\pi R^3}\right]^n$$

Where ΔP_{sprue} =pressure drop through sprue

n =*power low endix*

R = inlet radius of sprue

Q = flow rate

L= length of sprue

i. *Runner design*

Standard Runner Sizes

utilization and more balanced melt flow, then nonstandard $V_{runner} = \pi r^2 xL_r = \pi x(0.003)^2 x0.008 = 2.262x10^{-7}m^3$ since the runner is two, the volume becomes $V_{runner} = 2x2.262x10^{-7}m^3 = \mathbf{4.\ 524x10^{-7}m^3}$

$$\Delta Prunner = \frac{2x\eta L}{R}\left[\frac{(3+\frac{1}{n})Q}{\pi R^3}\right]^n$$

$$\Delta P_{runner} = \frac{2x745x0.008}{0.004}\left[\frac{\left(3+\frac{1}{0.197}\right)x1.293x10^{-3}}{\pi(0.003)^3}\right]^{0.197}$$

$= 29991.8Pa \approx 0.3bar$

i. *Gate design*

Number of gates are two that connect the two cavities with runner

Taking the dimensions

Diameter=5mm

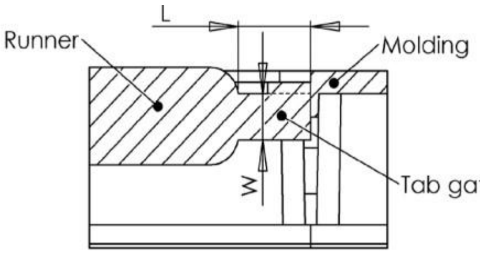

Figure.18. gate

Volume of the gate is calculated likewise as above= $\pi r^2 xL_g = (0.002)^2 x0.008 = 1.005x10^{-7}m^3$

Pressure drop thought the gate is calculated as

$$\Delta Pgate = \frac{2x\eta L}{R}\left[\frac{(3+\frac{1}{n})Q}{\pi R^3}\right]^n$$

$$\Delta P_{gate} = \frac{2x745x0.008}{0.002}\left[\frac{\left(3+\frac{1}{0.197}\right)x1.293x10^{-3}}{\pi(0.002)^3}\right]^{0.197}$$

$= 76225.99Pa = 0.76226bar$

The total pressure drop injection system and feed system is

$\Delta Ptotal = \nabla P + \Delta Pn0zzle + \Delta Psprue + \Delta Prunner + \Delta Pgate$

$= (172.08 + \mathbf{0.\ 06018} + \mathbf{0.\ 497} + 0.3 + 0.76226bar)\ r$

$= \mathbf{173.\ 73bar}$

The total melt volume through the machine for one production is

$Vmelt = V + VN + Vsprue + Vrunner + Vgate$

$= 7.462x10^{-4}m^3 + 1.178x10^{-4}m^3 + 1.2566x10^{-6}m^3 + 4.524x10^{-7} + 1.005x10^{-7}m^3$

$= 8.66x10^{-4}m^3$

i. Plunger design

In this design plunger is used to inject the melt polymer to the mold that come from screw.

In the injection plunger design, the volume of the melt (V) the plunger can successfully have pushed from the barrel can be determined by knowing the diameter of the plunger. It goes thus:

$$Vmelt = \frac{\pi}{4}(D_p)^2 x L_p$$

Where

V_{melt} = volume of acetal homopolymer melt = $8.66x10^{-4}m^3$

D_p = diameter of plunger=80mm

L_p = length of plunger

Then $L_p = \frac{V_{melt}x4}{\pi {D_p}^2} = \frac{8.66x10^{-4}m^3x4}{\pi x0.08^2} = 0.17m$

L_p = 170mm

Length of plunger rode=1500mm with diameter of 70mm

□Plunger is hydraulically operated

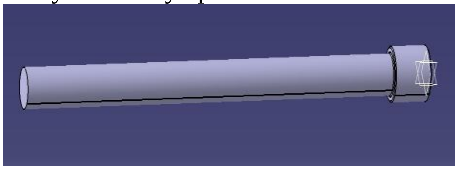

Figure.19. plunger

The allowable stress of mild steel is given below which is 225MPa

Therefore, the design of plunger is safe.

The diameter of the plunger is similar to inner diameter of barrel that plunger moves through.

Therefore $D_p = 80mm$

Then the length of plunger is calculated from the melt volume as follow

$$\sigma_c = \frac{{R_i}^2 P}{{R_o}^2 - {R_i}^2}\left(1 + \frac{{R_o}^2}{{R_i}^2}\right)$$

$$= \frac{(60.5)^2 x117.2}{(115)^2 - (60.5)^2}\left(1 + \frac{(115)^2}{(60.5)^2}\right)$$

$= 206.9MPa$

The allowable stress of mild steel is given below which is 225MPa

Therefore, the design of plunger is safe.

i. Design of barrel for screw

Barrel is hallow cylinder that melts the ingot polymer and the station of screw pushes the polymer through barrel.

The barrel material is mild steel.

barrel dimension is taken from the standard table-7 above Outer diameter of barrel D_o=230mm length of barrel=2405mm hopper inlet diameter=150mm

To find the inner diameter of the barrel we must be consider the clearance between screw to barrel it listed below the table

Table 3.screw-barrel clearance table

Screw diameter	Max. clearance(mm)	Min. clearance(mm)
80	0.3	0.2
90	0.35	0.25
100	0.375	0.275
105	0.4	0.3

Therefore, inner diameter of barrel,

D_i=2x0.375+D=0.75+120=120.75mm≈ $121mm$

Thickness of barrel $t_b = (do - di)/2 = \frac{230-121}{2} = 54.5mm \approx 55mm$

Let's check the circumferential and longitudinal stress at barrel

Where R_i =internal diameter of barrel

R_o = external diameter of barrel

P = injection pressure=117.2MPa

Assume the safety factor of the barrel is 2. The the allowable stress of mild steel is

$$\sigma_{all} = \frac{\sigma_s}{S.F} = \frac{450MPa}{2}$$

= 225MPa therefore $\sigma_c < \sigma_{all}$ then the barrel is safe with injection pressure

Radial stress (σ_r) is calculated as follow

$$\sigma_r = \frac{{R_i}^2 P}{{R_o}^2 - {R_i}^2}\left(1 - \frac{{R_o}^2}{{R_i}^2}\right)$$

$$= \frac{(60.5)^2 x117.2}{(115)^2 - (60.5)^2}\left(1 - \frac{(115)^2}{(60.5)^2}\right)$$

= −117.2

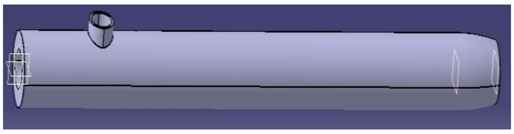

Figure.20. barrel of screw

Dimensions

The magnitude of σ_r is less then allowable stress of mild steel, therefore design is safe.

ii. Elbow design

a) This is used to transfer the melt polymer from barrel of screw to plunger

In order to withstand that temperature and pressure its thickness must be large internal diameter is more less.

Inner diameter=60mm

Outer diameter=100mm

Thickness =30mm

Height of elbow=100mm

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The figure below shown is elbow for this design

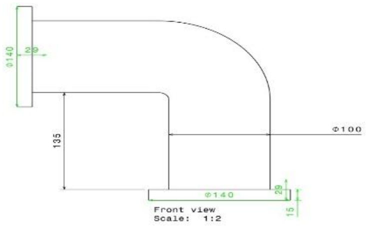


Figure.21. Elbow Barrel Heater

The heat profile of conductive heat generated with heater bands is probably the most important and perhaps least understood factor in successful plastics processing or design of plastic molding machine.

An incorrect heat profile is the most frequent case of wear in barrel and screw, because the natural tendency is cool down the heater bands when a heat override condition occurs. Since most heat overrides are caused by excessive shear heat, the best way to decrease shear is to apply more, not less conductive heat. It will not increase the temperature of the melt but instead, changes the source of heat energy used to melt the plastic.

For this design the barrel heater is selected based on the standard listed below table

Table 4.Barrel heater standard

Heater internal diameter (mm)	Heater width (mm)	Maximum barrel temperature (C^0)	Maximum sheath temperature (C^0)	Nominal W/in^2	Barrel Type
23.8 to 156	15.9 to 51	399	482	19-48	MB Mica Insulated 1 Piece
76 to 305	51	482	649	24-44	HBT Tubular Barrel
89 to 254	38 to 51	399	482	20-40	MB Mica Insulated 2 Pieces
23.8 to 406	63.5	427	649	29-36	DBW Flexible Band
127 to 508	38	427	649	20-82	HB Strip Type
127 to 737	38	427	649	24-42	DB Flexible Band

Let the barrel type is HBT Tubular Barrel then from the table we can select inner diameter depending the outer diameter of the barrel which is 230mm

Therefore, inner diameter of heater =230mm

Outer diameter of heater=270mm

Thickness of heater=20mm

Width of heater=51mm

Assuming the space between two heaters as 50mm

Then we can evaluate the number of heater coil needed

$$2(number\ of\ heater x 51 + number\ of\ heater x 50) = length\ of\ barrel$$

$$202mm * number\ of\ heater = 2405mm$$

$$number\ of\ heater = \frac{2405mm}{202mm} = 11\ barrel\ heater\ is\ needed$$

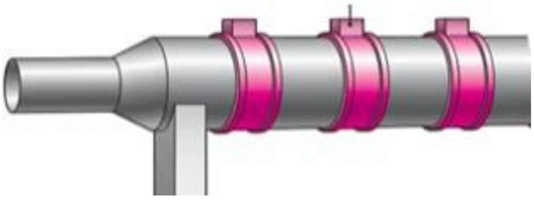


Figure22(a). barrel heater

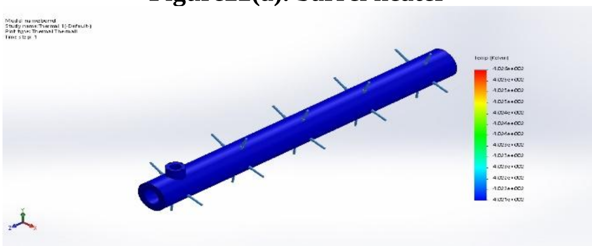


Figure 1(b) . The heat analysis of barrel by using ANSYS

iii. Design of plunger barrel

This barrel like that of the screw barrel but it has no heater. It simply cylinders with high pressure.

Dimension

The inner diameter is equal to plunger diameter with considering clearance maximum 0.3mm and minimum 0.2mm (table-8) taking minimum 0.2mm since plunger needs minimum clearance

Therefore, inner diameter $D_i = 80.4mm$

The outer diameter D_o =180mm taken from above table-7

Length of L=1480mm=1.48m

iv. Design of mold cavity

Cavity design is depending on the product, so in this project two product at a time is produced.

Mold cavity is design by CATIA software as follow

In addition to cavity there are also other features like ejector hole, guide pin hole, runner and cooling systems.

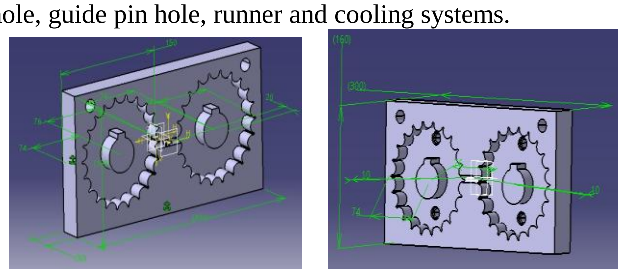


Figure 2. Stationary or fixed mold

Figure 3. Movable mold

All necessary dimensions are shown on the drawing above and the mold temperature is 93℃ given at the above table 6.

IV. MANUFACTURING PROCESSES

4.1. Prototype manufacturing process

Prototype manufacturing has a great contribution in order to make feasible this work and understand the working mechanism of the designed machine. In addition to this prototype manufacturing, it helps develop practical work skill on different machine works, like welding, grinding, cutting machine, drilling. After design and proper material selection the next steps are carried out in prototype manufacturing process.

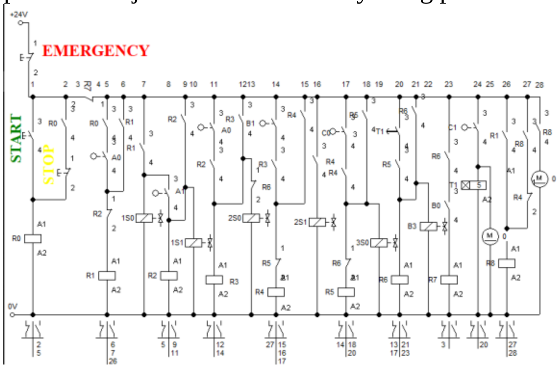
To manufacture this project prototype there are various processes such as:

During cutting process measurement have great contribution in order to cut materials at specific measurement because materials must be cut economically.

Figure:25. cutting process

Surface Finishing: During the prototype manufacturing by using grinding and filing surface finish was achieved.

3.Assembly: In this project final assembly is done to understand the working principle of the study most components are join and assembled by using pin.



4.Electrical system installation: This manufacturing process involves arranging and integrating different electrical and mechanical systems such as electric motor, hydraulic system, and sensor those required for the prototype automations

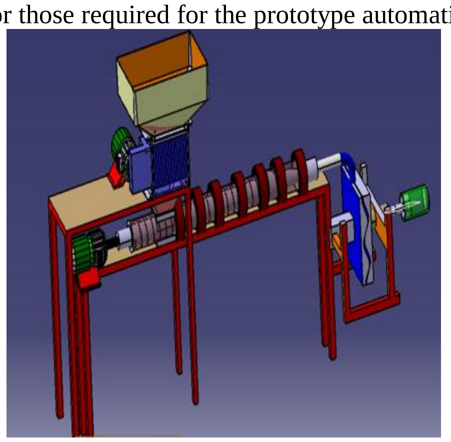


Figure.26. Assembly drawing of the machine.

Prototype Testing: The manufactured automatic waste plastic recycling machine is tested for cutting the plastic

Figure.27. Prototype Testing

V. RESULTS AND DISCUSSION

5.1 Results

Based on an amount of experimentation, several conclusions can be made regarding the use of extruder and shredder for combustion research The PC is high flow rate because of low density. The large particles of plastic need to be broken down into small pieces to melt simply, reduce storage and transportation space requirement. **Shredder machine**; - product/mass flow rate (HDPE) increase when speed of motor is rise. **Extruder machine**; - product increases when the die geometry is great and the density of polymers are low.

There are several ways of determining efficiency of the machine. The efficiency of the machine is calculated as follows:

efficiency = Output weight (Kg)/Input weight (Kg) X100%

Input = 12.8 Kg

Output= 10.2 Kg

Therefore; Efficiency = $(\frac{10.2kg}{12.8})x100\%$

Efficiency =79.69%

=80%

After testing the plastic shredder machine, it shredded the plastic waste into the desired chips or raw materials. Conclusively, the efficiency of the machine is about 80% which is an indication that the machine will be able to serve its purpose. Having a capacity of delivering up to 20.4 kg of finished plastic blocks per hour. It has the working capacity of almost three full cycle per minutes, which gives the production rate of 180 products per hour.

5.1.1. Results from analytical data

A. Anises and analytical analysis of shaft

(1) Static structural analysis

Total deformation, total equivalent stress and equivalent elastic strain are obtained for this analysis and maximum sheer stress. A static analysis is performed over a structure when the loads & boundary conditions remain stationary and do not change over time it is assumed that the load or field conditions are applied gradually, not suddenly. **Solved for three factors:**

1. von Mises Stress
2. total Static displacement
3. Stress strain

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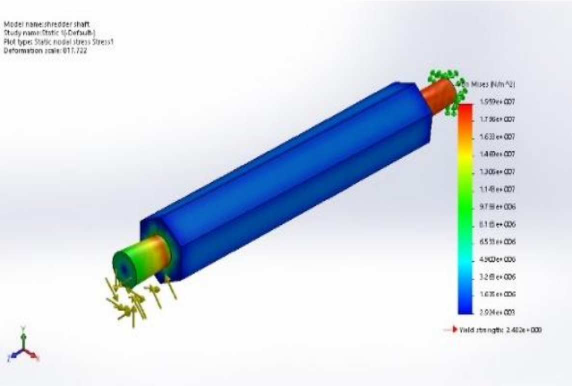


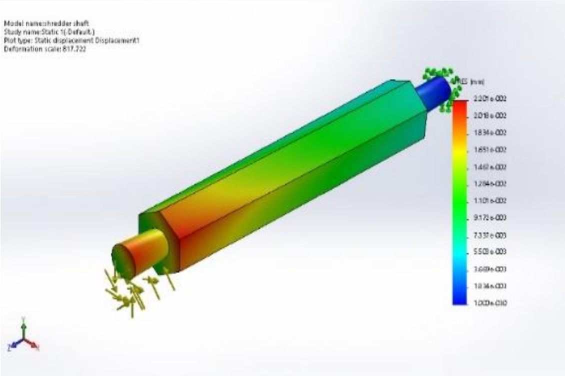


Figure 28. Von Mises Stress
Figure 29. Total Static displacement

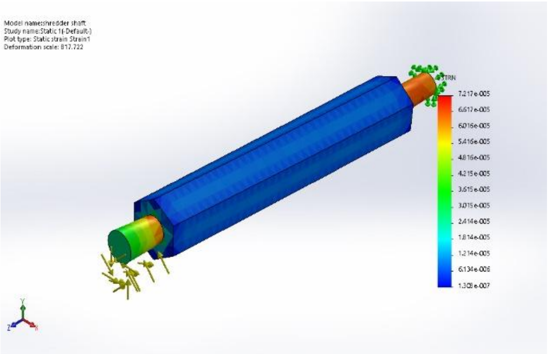


Figure 30. Stress strain

Table 5.Static Structural result summery

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2923.69 N/m^2 Node: 3703	1.95923e+007 N/m^2 Node: 9085

Analytical result of shaft
Diameter of shaft is 20mm
Sheer stress of material τ =11.17kj

(2) Discussion of shaft

From the analytical and anysis is some difference this difference is generated from anysis software; so the design is safe.

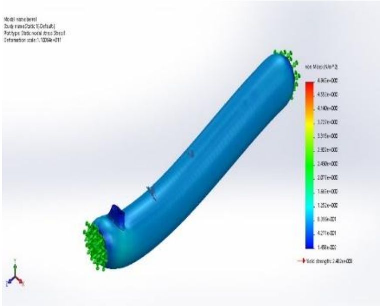
(3) 5.1.2 Anysis and analytical analysis of barrel

(4) Static structural analysis

(5) Statically analysis of barrel

Solved for three factors:

- Vons stress
- Total deformation
- Equivalent stress static strain strain



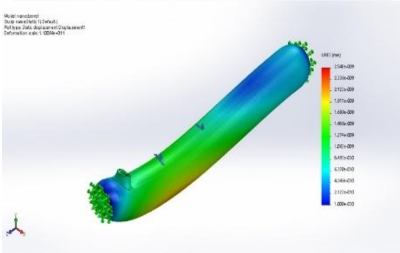


Figure 31. Von Mises Stress Figure 32. Static displacement

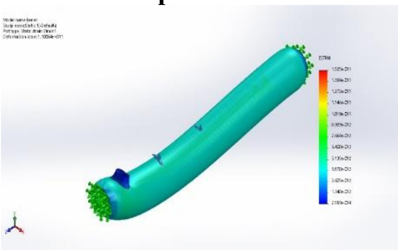


Figure32. Equivalent Strain

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0145753 N/m^2 Node: 12782	4.96497 N/m^2 Node: 12833
Displacement1	URES: Resultant Displacement	0 mm Node: 73	2.54789e-009 mm Node: 289
Strain1	ESTRN: Equivalent Strain	7.55887e-014 Element: 3064	1.52531e-011 Element: 3838

Table 6. Static Structural analysis of barrel Results summery

Thermal analysis of barrel

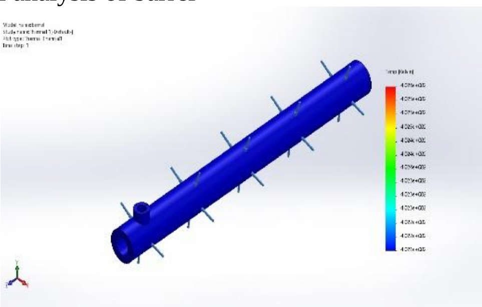


Figure 34.thermal analysis

Analytical analysis
Let the barrel type is HBT Tubular Barrel then from the table we can select inner diameter depending the outer diameter of the barrel which is 230mm
Therefore, inner diameter of heater =230mm
Outer diameter of heater=270mm
Thickness of heater=20mm
Width of heater=51mm
Assuming the space between two heaters as 50mm
Then we can evaluate the
number of heater coil needed

$$2(number\ of\ heaterx51 + number\ of\ heaterx50) = length\ of\ barrel$$

$$202mm * number\ of\ heater = 2405mm$$

$$number\ of\ heater = \frac{2405mm}{202mm} = 11\ barrel\ heater\ is\ needed$$

b) Desiccation

From the analytical result of working maximum stress is 235.88Mpa and the anysis maximum stress is 263.5Mpa from this result we conclude that the design is safe because from the anysis figure indicates the result is at safe level.

1. Temperature range
2. Total heat flux

From the result temperature range is minimum 96^{o}c and maximum result is 295^{o}c and minimum total heat flux of the mold is 2.2101e-010 W/m² and maximum total heat flux is 1.6489e-005 W/m² this indicates this material and design is safe from the figure indicated above.

VI. CONCLUSIONS AND RECOMMENDATION

6.1. Conclusions

This waste plastic recycling machine has been developed using locally available materials. The flakes can be re-extruded for production of colored plastic products and composites. The actual motivation behind this is to increase the awareness of recycling and make it accessible to the public. The machine is fairly low power consuming. If implemented and developed properly, there is a definite potential for its application in the improvement of the environment.

6.2. RecommendationThe results obtained from the waste plastic recycling and designing that involved in this project in addition to other advantages which list on the above. For who are interested to work on this area we recommended that;To review the design in general and blade part specifically. To manufacture the real machine as per design and test the machine.To design the machine with alternative power source.

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