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Design and Fabrication of Small Scale Plastic Recycler

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Abstract

The aim of our project is to Design and fabrication of small-scale plastic recycler. The main principle is to compress the plastic material in a barrel and motor with belt arrangement develops the compressing motion. The plastic materials are poured in a barrel. The heater surrounding the barrel heats the plastic material. Then it is converted into molten state. The molten plastic is injected through the nozzle in a barrel to the die by the compressing force. The die is placed just below the nozzle. After completing the process, we will get the product from the die. Different shape of the component can be made according to the die what are used. Commercial product like bushes, couplings, switches etc. can be produced.

Keywords: *barrel, extrusion screw, motor, gearbox, pulley.*

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I. INTRODUCTION

The literature search was mainly focused on the types of plastics, effects of plastic dumping, available methods for plastic recycling. We have also studied briefly about the large-scale plastic recyclers which is used in different countries. we are expecting a positive result in favor of society and sustaining the nature and ecosystem for the upcoming generation. Dominick v rossato in his paper extruding plastics, a practical processing handbook explains. The practical factory reviews of extrusion process. It also provides the guidelines for maximizing the efficiency of the extruding machine. the theoretical approaches are included in the paper. however, the books practical approach provides the trends and technologies in extrusion process (4). The design and built of crusher machine of plastic bottles by a uzir,k ishak , norfizah deals with the design and specifications of a crusher machine. A pet bottle crusher is designed as with shredding process used (3) It also broadly explains the components and its materials needed to crush a pet bottle. Design of used plastic crushing machine for small scale industrial applications by ikepan aniekan, owunna ikechukwu explains the Significance of the crusher machines (1). In this paper they describes about the work rate these kind of machines and its practical analysis and calculations.

1.1 PROBLEM DEFINITION

The main aim of this work is to reduce the plastic waste that is rising in the present world and to achieve this; a system is designed incorporating a plastic extruder which plays a prominent part in recycling waste plastic into useful products. This work uses waste plastics and converts them into building materials with the help of an extruder, thereby reducing the plastic waste which is a key factor for environmental pollution.

Presently waste plastics are effectively converted into useful building materials like bricks, interlocks, roof tiles, railway sleepers, paving slabs, retaining blocks etc., using either single origin plastic waste material or a mixture of different plastic wastes along with waste rubber powder as filler. After conducting several trials with the variety of plastic wastes processed into composite brick, it was observed that the maximum compressive load sustained by the Polypropylene/Rubber composite brick is 17.05 tons followed by LDPE/Rubber composite brick with 16.55 tons which is much higher than the clay brick which sustained only 9.03 tons.

1.2 WORKING

Waste products taken from waste plastic are dried for two to three days. The heating chamber switch was switched ON so that the regulator has to be adjusted gradually to reach the maximum temperature. Then it was allowed to heat up to five minutes. Then motor was switched ON. Thus screw conveyor rotates. The conveyor has taken it inside the hopper. Inside the extruder more heat is generated because the heat is transferred from heat chamber to the extruder. Thus, the plastic waste burnt inside the extruder. Switch on the heater and set the required temperature slightly above the melting point of different waste plastics. Mixing waste plastics, rubber composites and calcium carbonate in required quantity and is poured into the hopper when the required temperature in the control box has reached. Switch on the motor and the screw conveyor starts rotating at 80 rpm. The waste plastics from the hopper gets melted and conveyed towards the nozzle. A brick mold is kept at the end of the nozzle tip and the molten plastic/rubber composite material starts filling the mold box. After the mold is filled completely the mold box is removed from the nozzle tip dipped in the water bath and kept inside the bath for an hour for proper cooling. The final product is removed from the mold box and is sent for compression testing using Hydraulic Brick testing machine.

II. WORKING PRINCIPLE

This project is based on the process of plastic waste management system. It is consist of mechanical part mainly electric AC motor, hopper, gear box, blades, heating coil, belt, pulley, controller, and nozzle. The crushing units are rotate in direction to squeeze the bottle pieces and the controllers driven by a gear box. The ac motor and belt drive arrangement is mainly used to rotate the recycling unit and the gear box used for the purpose control the speed of the motor. In order to perform this rotation we have adopted meshing arrangement from the motor. The machine is provided with the opening at the top side recycling unit. The waste plastic pieces are kept inside the hopper. Simultaneously the bottle pieces will fall on crushing hopper on the bottle gets melting by the heating coil. The melting plastics are collected for the purpose of further uses.

2.1COMPONENETS

2.1.1 SINGLE PHASE MOTOR:

The motor is so chosen in such a way that it is used to drive the worm and worm wheel drive. The ratio have been reduced drastically of about 40:1 ratio. The motor selected is AC such that it needs to sustain single phase 0.25 hp motor.

Figure 1: Single phase Motor

2.1.2 EXTRUTION CYLINDER

It is the pipe chamber where the moving product is to burn. Screw conveyor is to be inserted through the chamber, for carrying the product inside. Generally the heating chamber should withstand high capacity of heat so this part has been made of mild steel.

Figure 2: Extrusion Cylinder

2.1.3 EXTRUSION SCREW

The screw is an essential component of a plastic extrusion machine. Through its turning motion inside a tight fitting barrel, the screw conveys the plastic, melts it and forces it through a die. These three steps are carried out in a continuous process capable of producing extrusions in a variety of lengths. The basic extrusion screw has three distinct parts, each engineered to do a specific task. The feed section is in the rear of the screw, where plastic pellets are gravity fed from above and conveyed forward. The length to diameter ratio of the feed section is typically four or five to one, which is sufficient to build up the pressure needed to transport the plastic. However, the friction between the barrel wall and the plastic must be greater than that between the screw and the plastic in order for lateral movement to occur.

Figure 3 : Extrusion screw

2.1.4 BAND HEATER

These are the heating element which fixed around the heating chamber and screwed. They were connected to the power supply and produced heat over the heating chamber. So that, the heating chamber gets heated. They were controlled by the electrical control switches.

Figure 4: Band heater

2.1.5 HOPPER

It is the feeder part shaped like a truncated pyramid. It is welded on the hopper barrel. The product is fed through this hopper to the hopper barrel. This Hopper is generally made of steel sheets by the use of welding and riveting operations.

Figure 5: Hopper

2.1.6 FRAME

It is the base part of the equipment where all the parts have been mounted. It is fabricated by the number of angle plates welded with each other. It absorbs all the vibrations through the vibration resisting bush fixed at each leg of supporter and forces of other parts during the working condition.


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Figure 6: Frame

2.1.7 SHAFT

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque setup within the shaft permits the power to be transferred to various machines linked up to the shaft. In this equipment the power from the motor is transmitted to the gear box by the transmitting shaft. The transmitting shaft is made of mild steel and is of cylindrical in shape. The diameter of the shaft used here is of 20mm. The length of the shaft used is about 850mm.

Figure 7: Shaft

2.1.8 WORM GEAR

The worm gears are widely used for transmitting power at high velocity ratios between non-intersecting shafts that are generally but not necessarily at right angles. It can give velocity ratios as high as 300:1 or more in a single step in a minimum of space but it has lower efficiency. The worm gearing is mostly used as speed reducer which consists of a worm and a worm wheel. In this equipment the worm gear used is of cylindrical or straight worm and can obtain a velocity ratio of 30:1.

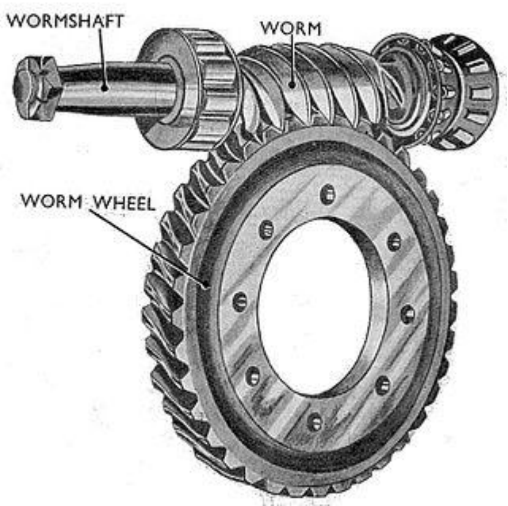

Figure 8: Worm gear

2.1.9ROLLER CHAIN DRIVE

Roller chain or bush roller chain is the type of chain drive most commonly used for transmission of mechanical power on many kinds of domestic, industrial and agricultural machinery, including conveyors, wire- and tube-drawing machines, printing presses, cars, motorcycles, and bicycles. It consists of a series of short cylindrical rollers held together by side links. It is driven by a toothed wheel called a sprocket. It is a simple, reliable, and efficient means of power transmission.

2.1.10 Sprocket

This is a cycle chain sprocket. The chain sprocket is coupled with another generator shaft. Sprockets are similar to pulleys in that the driver and the driven rotate in the same direction whereas two meshing gears would reverse the direction of rotation. Sprocket teeth engage with a roller chain to produce the very positive non-slip drive commonly used on bicycles.

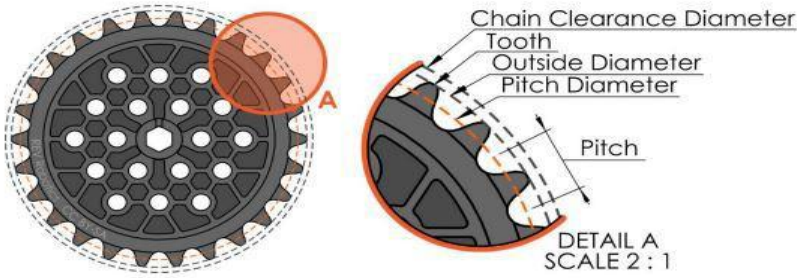

Figure 9: Sprocket

III. FABRICATION PROCESS

3.1 FABRICATION PROCEDURE:

The fabrication starts along with the parts such as bushes, among the extruder sides then all the flanges are connected each other using five bolts and nuts. Then finally the total assembly was placed have been carried out. We have purchased all materials related to our project for assembling and to get full working of the project. Materials involved in our project are;

i) Sheet metal (1.5mm thick)
ii) Steel pipe (9.5mm thick)
iii) Copper sheets (1mm thick)

In this project first the sheet metal was cut into 300*300mm length and Height and welded using carbon are welding. A pipe of diameter (140mm) have been gas cut to a hole and welded with hopper and inner dia of flange (140mm) also to be welded. Then an extruder was turned and faced using lathe. Then two flanges were also welded at the two sides of the extruder.

A bend pipe of (1.5mm) of thickness was manufactured by welding of two pipes with each other and another side of bent pipe was welded with the flange.

The flange has five holes use to attach with each other parts. Then the panel box is purchased and a hole was made by gas cutting for arrangements of switches and indicators. Then panel box was welded with the stand. The stand of (700mm) height was made with (2.5mm) thick L-angles and welded with each other.

Finally, the location of motor, gearbox, hopper, extruder passage is located and drilling operation on stand has been done.

Screw conveyor was made by cutting 1mm thick by gas cutting of diameter of screw (100mm dia). Thus, all the gas cut parts were joined each other among the hollow pipe of 25mm diameter and those was allowed inside. Bushes wee located at two ends of pipe passage. Finally, welding was done for mishap among the base plate and joined by nuts and bolts.

Then motor was placed at the place so that the drive is to be given to the conveyor – for the reduction through the gear box. The shaft in the gear box and conveyor shaft was joined using adjustable bracket.

Then motor drive was given by means of (7470 no) Vee-belt. Then copper plates was bended around for diameter (dia 140 mm)-3 in Number which has filament that is to be brazed among them for supply of current to give heat for extruder.

Then power supply of (15 amp) was given so that the heat was generated; with the use of say (3000watts) to heat coil copper plates. The above procedure completes the fabrication of our project.

3.2 FABRICATED PARTS:

3.2.1 Hopper:

i) Material: SHET METAL.
ii) Size (300*300) Length*Breadth*height)
iii) Welding process.

3.2.2 Extruder:

i) Material: steel pipe.
ii) Size: (length and breadth)
iii) Process: welding, lathe work.

3.2.3 Stand:

i) Material: steel Plate (L-angle)
ii) Size: 2mm thick.
iii) Process: welding.

3.2.4 Gearbox:

i) Material: steel plate (2mm thick).
ii) Size: (110*100mm) (length * width)
iii) Process: cutting process.

3.2.5 Gears:

i) Material: Worm & Worm wheel both of cast iron.
ii) Size: worm (40mm) worm wheel (60mm)
iii) Process: Hobbling process and milling process.

3.2.6 Shaft:

i) Material: mild steel.
ii) Size: diameter 25mm.
iii) Process: lathe work.

IV. DESIGN AND ANALYSIS

4.1 DESIGN

The structural design consists of extrusion barrel, hopper, power drives (motor, roller chain drive and worm gear) and frame. The frame, extrusion barrel and hopper are made of GI angle, GI pipe and GI sheet respectively. All functional components are fitted on the frame.

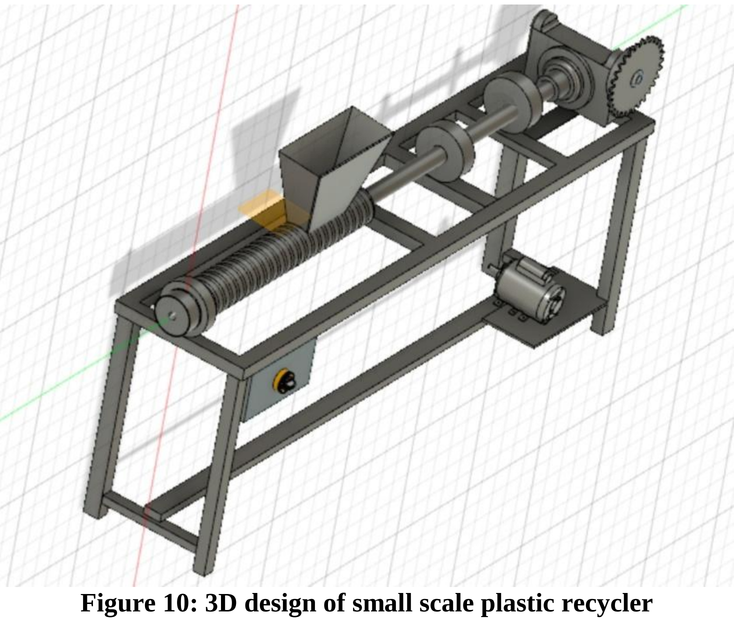

Figure 10: 3D design of small scale plastic recycler

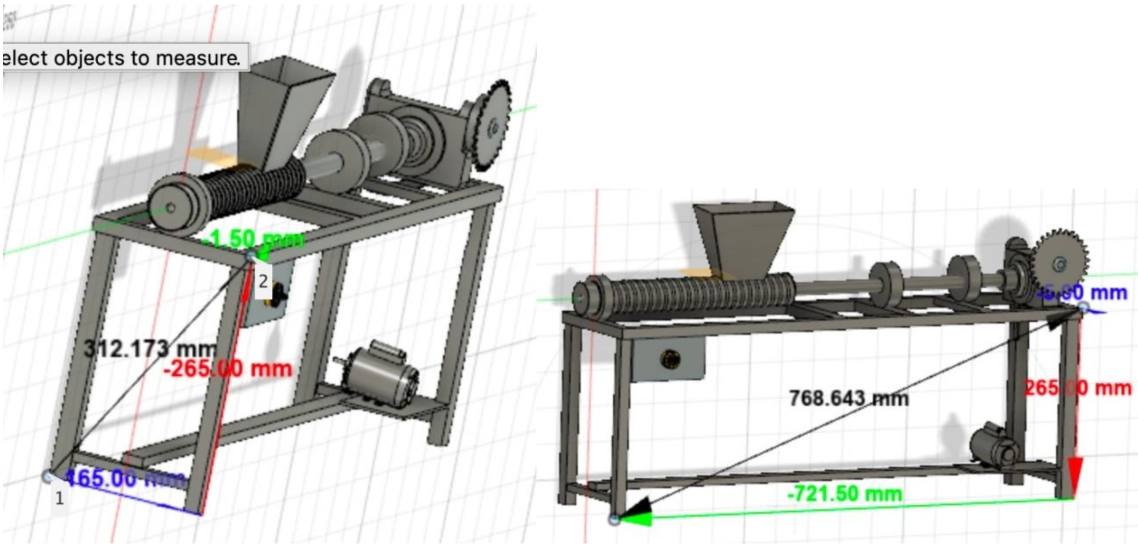

Figure 11: Dimension of frame

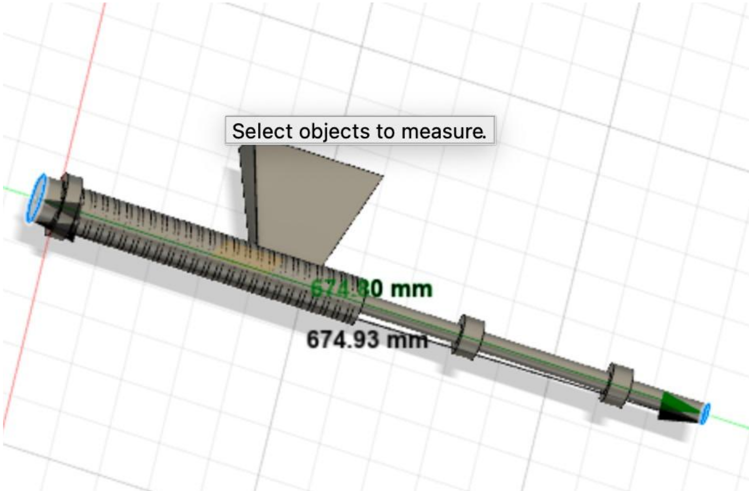

Figure 12: Dimension of extruder

4.2 ANALSIS

4.2.1 Safety Factor

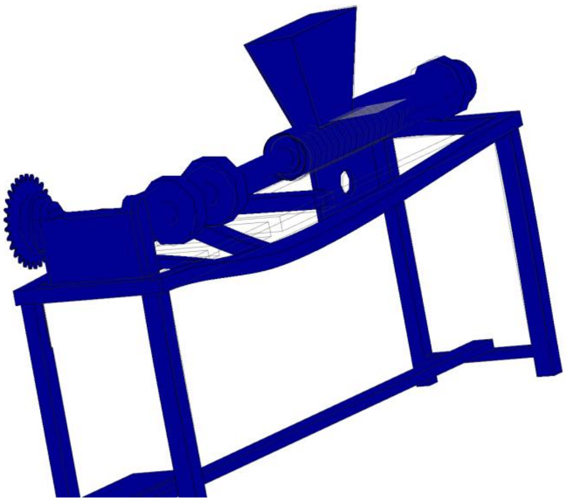

Figure 13: Safety factor analysis

The analysis of the frame was done by using Fusion 360 stimulation. A momentum of 66666.67 was applied along the shaft. The value was found using drawing bending moment diagram. The safety factor was found to sustain the load. The safety factor was found to be 12 min to 15 max which is the ratio of ultimate stress to the maximum allowable stress.

4.2.2 Stress Analysis

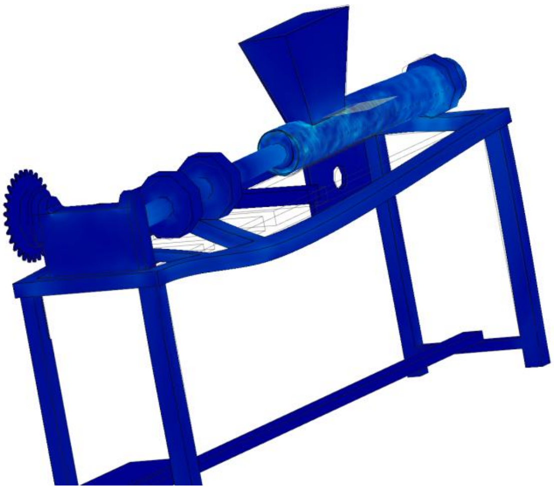

Figure 14: Stress analysis

Stress analysis was done using von Mises stress theory and the maximum allowable stress were found as 24.29 which is less than ultimate strength of material that is 350Mpa, which shows the design is safe.

4.2.3 Strain

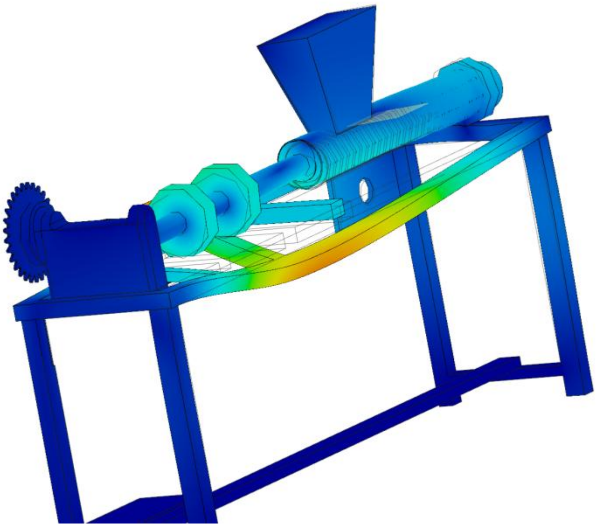

Figure 15: Strain analysis

The momentum applied was 66666.67 MPa along the shaft axis and a 100 N force was applied through hopper as the material gets to enters through this. Maximum deformation was found at the shaft and a comparable deformation has happened at the barrel hopper joint. The strain was found to be 1.973 MPa.

V. DESIGN CALCULATIONS

5.1 SHAFT DESIGN CALCULATION

Diameter of shaft d = 15 mm

Torque transmitted through a shaft,

T mean = (P*60)/ (2* Π*N), Where, P = Power of motor in KW, N = Speed in rpm

T = (0.5*10^3*60)/ (2*Π*1440), **T = 3.315 KNm**, **T = 3315.7 Nmm**, Tmax = 1.2*Tmean

Tmax = 1.2*3315.7. **Tmax = 3978.84 Nmm**

Shaft is subjected to shear stress,

T = σ *(Π /16) *d^3, σ = (3315.7*16)/(Π*15^3), σ **= 5 N/mm^2**

Shaft subjected to bending stress

M/I = σb/Y

Where, M = Bending moment

I = Moment of Inertia of cross-sectional area of the shaft.

M = m*g*L, M = 0.15*9.81*300, M **= 441.45 Nmm**, I = (Π*d^4)/64, I = (Π*15^4)/64

I = 2485.04 mm^4, Y = d/2**, Y** = 15/2**, Y = 7.5 mm**

Therefore, σb = (M/I) *Y, σb = (441.45/2485.04) *7.5, σ**b = 1.332 N/mm^2**

5.2 WORM GEAR CALCULATIONS

Input speed = 1440 rpm

No. of stages in reduction = 2

Worm Gear:

Reference diameter d1 = q* mx = 11*1.4 = 16 mm

Tip diameter da1 = d1+2*f0*mx = 16+2*7*1.4 = 36 mm

Where f0 is the height factor and here it is taken as 7.

Tip relief diameter = 0.1* mx = 0.1*1.4 = 0.14 mm

Root relief radius r2 = 0.2*mx = 0.2*1.4 = 0.28 mm

Nominal tooth thickness reference to diameter in axial section,

S = Π*mx/2 = Π*1.4/2 = 2.199 mm

Nominal tooth thickness reference to diameter in normal section,

Sn = Π/2 *mx*Cos ɣ

ɣ = $\tan^{-1}$ [z/q] = $\tan^{-1}$ [1/11] = 5.19

Sn = Π/2 *1.4*cos (5.19) = 2.190 mm

WORM WHEEL:

Reference diameter d2 = Z*mx = 28*1.4 = 39.2 mm

Tip diameter da2 = (Z + 2*7+2x) x 1.4 = 58 mm

Pitch diameter d2 = 39.2 mm

Where, ɣ = $\tan^{-}$ [1/q] = $\tan^{-}$ [1/11] = 5.1944

Sn = (Π/2) *1.4*Cos (5.1944) =2.1901 mm

Length of worm,

L ≥ (11+0.06*Z) *mx

≥ (11 + 0.06 *41) *1.4

≥ 18.844 mm

Total length, L = 18.844 + 25 = 43.844 mm

For (Z=1) no of Starts.

No. of thread on Worm = L/3 (Π – Mx)

=18.844 / (Π – 1.4)

=3 Nos.

Speed in gear box:

N1/N2 = D2/D1 = Z2/Z1

Where,

N1 = Input speed to the gearbox = 436 rpm

N2 = Output speed from the gearbox

D2 = Diameter of the worm wheel = 50mm

D1 = Diameter of the worm gear = 36 mm

Z1 = Number of starts in the worm gear =1

Z2 = Number of teeth on worm wheel = 28 Nos.

∴ N2 = (Z2/Z1) *N1 = (28 / 1) *436 = 15 rpm

VI. CONCLUSION

This work effectively converts waste plastic into useful building materials like building bricks and floor interlocks which can effectively reduce the environmental pollution and further decreases the problem of waste plastics in the society. Rather than the waste plastics going into the landfill or incinerators it can be used as construction materials at a much lower cost after undergoing certain specific processing.

It also reduces the construction cost by eliminating the use of mortar during construction by using recyclable plastic/composite bricks and floor interlocks. From the compression testing results we come to know that waste plastics material when effectively mixed with Rubber powder and Calcium Carbonate gives the highest compressive strength and sustains high compressive load.

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