

# Design of Municipal Dry Waste Segregating Machine Using Conveyor

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**ABSTRACT:** In today's world solid waste management has become one of the main issues all over the country. With the progress of human civilization and rapid growth of population, the sources of waste are multiple and the waste generated become more complicated, as a result of it the environment is getting polluted day by day. To get rid of such type of unhealthy environment and health hazards the solid wastages must be taken care of by sorted into various components and then handled separately at the disposal for reused or recycling site. In order to recycle the solid wastages, they need to be segregated into various constituents. So, in this study, a mechanical machine for sorting of mixed domestic solid waste into its various componentis designed. The machine is designed with the major components being the belt conveyor, roller conveyor, air blower and a magnetic separation.

**KEYWORDS:** Recycling, handled, segregation.

## I. INTRODUCTION

Solid waste management is one of the major challenges faced by many countries around the globe. Solid waste is an unavoidable consequence of human's needs. The term solid waste refers to those waste materials, which is in solid form and has no value to the person who is responsible for it. Most of the people clean their own houses but never bother about their immediate surroundings and thus most of this waste has found its way into the streets and around the homes [2]. These types of improper and uncontrolled dumping create unhygienic surroundings, thus affecting the neighbouring community. So the only ways to manage solid waste is proper handling by sorted into various components and then handled separately at the disposal or recycling site [9]. Solid waste includes residential, industrial, commercial and agricultural waste. Collection, segregation and recycling of the waste are the main steps involved in waste management[4]. Waste segregation is the process of sorting the different types of waste constituents from the waste matrix. The processes like density separation, magnetic separation, air classification etc. are the method by which the sorting machine sorts the waste. By recycling the unwanted waste, an effort could be made towards reduction of volume of waste materials.

## II. MATERIALS AND METHODS/DESIGN

### 2.1. Design of Machine Elements.

**2.1.1. Design of hopper:** Hopper is a funnel-shaped structure which is used in feeding of materials. Light weight and corrosion resistance, Aluminium is selected as material for hopper.

$$\begin{aligned}L_1 &= \text{Top length of hopper} = 50 \text{ cm} & B_1 &= \text{Top breadth of hopper} = 50 \text{ cm} \\L_2 &= \text{Bottom length of hopper} = 25 \text{ cm} & B_2 &= \text{Bottom breath of hopper} = 25 \text{ cm} \\H &= \text{height of hopper} = 70 \text{ cm} \\ \text{Volume of inlet, } V_b &= L_1 \times B_1 \times H = (0.50 \times 0.50 \times 0.70) = 0.1750 \text{ m}^3 \\ \text{Volume of outlet, } V_{sm} &= L_1 \times B_2 \times H = (0.25 \times 0.25 \times 0.70) = 0.0437 \text{ m}^3\end{aligned}$$

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Volume of hopper,  $V_h = (V_b - V_{sm}) = (0.175 - 0.0437) = 0.1313 \text{ m}^3$

Discharge of hopper,  $M = \rho A \sqrt{Bg/(1+m)\tan\theta}$  (Eric Maynard)

Where,  $M$  = mass flow rate (kg/s),  $\rho$  = bulk density ( $\text{kg/m}^3$ ) =  $300 \text{ Kg/m}^3$

$g$  = acceleration due to gravity =  $9.81 \text{ m/s}^2$ ,

$B$  = outlet size (m) =  $0.25 \text{ m}$ ,  $m = 0$  (for pyramidal type hopper)

$\theta$  = mass flow hopper angle (vertically) =  $76^\circ$ ,

$A$  = cross sectional area of hopper

Thus, discharge of the hopper,  $M = 30 \times 0.25 \times 0.25 \sqrt{\frac{0.25 \times 9.81}{\tan 76}} = 14.6544 \text{ Kg/s}$

**2.1.2. Conveyor belts:** Conveyor belt is used for transmits material from one place to another. The materials used for belts must be strong, flexible, and durable. It must have a high coefficient of friction. Rubber belt of Flat Idler type is selected as the conveyor belt due to its reliability and other advantages.

The cross-sectional area of load on the belt is estimated using

$A = 0.16 \times B^2 \times C \times \tan \phi$  (Sadhu Singh)

Where,  $A$  = Cross sectional area of load on the belt

$B$  = width of the belt which is selected to have a value of  $500 \text{ mm}$ .

$t$  = thickness of the belt =  $10 \text{ mm}$

(R.S.Khurmi)

$C$  = a constant with a value between  $0.85$  &  $1$ . A value of  $1$  is selected.

$\Phi = 0.35 \times$  (static angle of repose). The static angle of repose is selected as  $45^\circ$  for municipal solid waste. (IS: 8730-1978) Thus,

$\Phi = (0.35 \times 45^\circ) = 15.75^\circ$ .

Therefore, the cross sectional area for load on the belt is

$A = 0.16 \times 0.5^2 \times 1 \times \tan (15.75^\circ) = 0.0113 \text{ m}^2$

Capacity of conveyor,

$Q_f = 3600 \times A_1 \times v \times \gamma$  (Sadhu Singh, 2005)

Where,  $v$  = conveying speed ( $0.5 \text{ m/s}$  to  $0.8 \text{ m/s}$ ) =  $0.6 \text{ m/s}$  (Considering),

$\gamma$  = specific weight of load =  $\rho \times g$ ,  $\rho$  = density of =  $300 \text{ kg/m}^3$  (Hristovski, 2007)

Hence,  $Q_f = 3600 \times 0.01128 \times 0.6 \times (300 \times 9.81) = 71705.60 \text{ N/hr} = 71.7050 \text{ KN/hr}$

The nominal volumetric capacity  $V = \frac{Q}{\gamma} = \frac{71.70}{2.943} = 24.36 \text{ m}^3/\text{hr}$

### 2.1.3. Design of Conveyor Pulleys and Shaft

Diameter of conveyor pulley drum,  $D = 105 \text{ mm}$

(Sadhu Singh, 2005)

Translational speed of the conveyor belt is

$N = \frac{60v}{\pi D} = \frac{60 \times 0.6}{\pi \times 0.105} = 109.1350 \text{ rpm}$

(R.S.Khurmi)

The full thickness longitudinal tensile strength is selected to have a value of  $160 \text{ KN/m}$  (Sadhu Singh, 2005) for belt of  $500 \text{ mm}$  width. Then, the tensile (peripheral) force,  $F$  in the belt is

$F = 160 \times 0.5$

(IS11592:2000)

$= 80 \text{ KN}$

For the material subjected to uncertain stresses and load, the factor of safety must have a value from  $9$  to  $12$ . So, considering the factor of safety to have a value  $10$ . (IS11592:2000)

Thus, the allowable tensile force  $F_{all}$  on the conveying belt is

$F_{all} = \frac{80}{10}$   
 $= 8 \text{ KN}$

Torque ( $T$ ) produced by this force around the pulley of diameter  $105 \text{ mm}$  is,

$T = F_{all} \times \text{distance} = F_{all} \times \frac{0.105}{2} = 0.42 \text{ KN-m}$

The power to be delivered to the conveyor belt through the pulley is

$P = F_{all} \times v = 8 \times 0.6 = 4.8 \text{ KW}$

(IS11592:2000)

The diameter of the shaft to drive the conveyor belt is estimated as,

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$$d = \sqrt[3]{\frac{16 \times T \times N}{\pi \times \tau_0}} \quad (\text{Sadhu Singh, 2005})$$

Where, T is torque produced around the pulley=0.42KN-m

N is the factor of safety which have a value range from 1.25 to 2  
and considering the value to be 1.5

$\tau_0$  is the maximum allowable shear stress, taken to have a value of  
55 MN/m<sup>2</sup> for commercial steel shafting (Sharma and Aggarwal)

$$\text{Thus, } d = \sqrt[3]{\frac{16 \times 0.42 \times 10^3 \times 1.5}{\pi \times 55 \times 10^6}} = 0.0388 \text{ m} = 38.78 \text{ mm}$$

Selecting standard value of diameter, d = 40 mm

(Sadhu Singh, 2005)

Let  $T_1$  = carrying side belt tension,  $T_2$  = return side belt tension. Then,

$$T_1 = T_E \left[ \frac{\xi}{e^{\mu\theta} - 1} + 1 \right] \quad (\text{IS 1159:2000})$$

Where,  $\xi$  = drive coefficient = 1.66

(Sadhu Singh, 2005)

Since the diameter of both the pulley drum are same.

Thus,  $\theta$  = Angle of wrap =  $180^\circ = 18 \times \frac{\pi}{180} = 3.1415 \text{ rad}$

$\mu$  = co-efficient of friction between drive pulley and belt = 0.35

$$\text{Hence, } T_1 = 20 \left[ \frac{1.66}{e^{0.35 \times 3.1415} - 1} + 1 \right] = 36.5772 \text{ kw}$$

$$T_2 = (T_1 - T_E) = (36.5772 - 20) = 16.1577 \text{ kw} \quad (\text{IS 1159:2000})$$

## 2.1.4. Selection of motor:

An induction motor of squirrel cage type is selected.

Power = 6 KW, Speed, N = 1000 rpm, Diameter of the motor shaft,  $d_m = 40 \text{ mm}$ .

## 2.1.5. Design of V-belt

V-belts are used to transmit power between two shafts by means of power friction. V-belts have a trapezoidal cross-section. As V-belts have more advantages over other belt for transmission of power from shaft to shaft. Therefore, V-belt is selected for the design.

Correction factor for service,  $F_a = 1.1$

(V.B.Bhandari)

Now, design power = ( $F_a \times$  transmitted power) = ( $1.1 \times 4.8$ ) = 5.28 kw

From the graph of speed of faster shaft (rpm) verses design power (kw), B-type belt is selected.

Now the pitch diameter of driver (smaller) pulley is selected as,  $d_s = 125 \text{ mm}$ .

Again, the pitch diameter of bigger (driven) pulley is

$$D_b = d_s \left[ \frac{\text{speed of smaller pulley}}{\text{speed of bigger pulley}} \right] = d_s \left[ \frac{\text{in put}}{\text{out put}} \right] = 125 \left[ \frac{1000}{109.135} \right] = 1145.37 \text{ mm} \quad (\text{V.B.Bhandari})$$

From the table a standard value of D = 1150 mm is selected.

Pitch length of belt,  $D_b + d_s$

$$L = \left[ 2C + \frac{\pi(D_b + d_s)}{2} + \frac{(D_b - d_s)^2}{4C} \right] \quad (\text{V.B.Bhandari})$$

$$= 2 \times 10^3 + \frac{\pi(1150+125)}{2} + \frac{(1150-125)^2}{4 \times 1000} \quad (\text{where, C is the centre distance, considering to have a value of 1 metre})$$

$$= 4265.42 \text{ mm}$$

Standard value of 4280 mm is selected.

(V.B.Bhandari)

To find the correct value of C, again putting the value of L in the above equation

$$4280 = 2C + \frac{\pi(1150+125)}{2} + \frac{(1150-125)^2}{4 \times C}$$

$$\Rightarrow 4280 = 2C + 2002.7653 + \frac{262656.25}{C}$$

$$\Rightarrow C^2 - 1138.6173C + 131328.125 = 0.$$

Solving the above equation we get the correct centre distance, C = 1008.3806 mm.

Now, the arc of contact of smaller pulley is

$$\alpha_s = 180 - 2 \sin^{-1} \left( \frac{D_b - d_s}{2C} \right) \quad (\text{V.B.Bhandari})$$

$$\Rightarrow \alpha_s = 180 - 2 \sin^{-1} \left( \frac{1150 - 125}{2 \times 1008.3806} \right)$$

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$$\Rightarrow \alpha_s = 118.9065^\circ \approx 119^\circ.$$

Thus, Correction factor of belt pitch length,  $F_c = 1.50$ . (V.B.Bhandari)

Correction factor for the arc of contact,  $F_d = 0.96$ .

Power rating ( $P_r$ ) [for 1000rpm, 125mm pulley] = 2.02.

$$\text{Number of belts} = \frac{P \times F_a}{P_r \times F_c \times F_d} = \frac{4.8 \times 1.1}{2.02 \times 1.50 \times 0.96} = 1.815 \text{ or } 2.$$

### 2.1.6. V-grooved pulley

The dimensions of V-grooved pulley are usually of grey cast of Grade-FG 250. (IS3142-1993)

The dimensions for B type V-belt is given as follows-

$l_p$  is the Pitch width of pulley groove or pitch width of belt. It is the width of the belt at its neutral axis. The line in the V-belt, whose length remains unchanged when the belt is deformed under tension, is called its neutral axis and is considering to have a value 14 mm.

$b$  = Minimum height of groove above pitch line = 3.50 mm

$h$  = Minimum depth of groove below the pitch line = 14 mm

$e$  = Centre to centre distance of adjacent grooves = 19.40 mm

$f$  = Distance of the edge of pulley to first groove centre. = 12 mm

$\alpha$  = Groove angle =  $34^\circ$

$d_p$  = Pitch diameter of pulley. It is diameter of the pulley measured at the pitch width of the groove up to 190 mm

$g$  = Minimum top width of the groove = 16.10 mm

For diameter up to 200 mm, no arms are required, pulleys are provided with solid web or a web with holes.

But for diameter above 450 mm, number of arms = 6 (standard) (P.C.Sharma&Agarwal)

### 2.1.7. Chain Drive

Velocity ratio of chain drive

$$V.R = \frac{N_1}{N_2} = 1 \quad (\text{Since, } N_1 = N_2)$$

Number of teeth,  $z = 31$ , Service factor = 1.25

(Table no. 21.5, R.S Khurmi)

Design power = rated power  $\times$  service factor =  $4.86 \times 1.25 = 6.0750$  KW

Based on the design power rating and speed of the roller

we have chosen ISO chain no. =  $16 \times B$

(Table no. 21.4 R.S Khurmi)

From table 21.1

(R.S. Khurmi)

Pitch, ( $p$ ) of the chain = 25.40 mm, Roller diameter of the chain = 15.88 mm

Width between inner plates ( $b$ ) = 17.02 mm

As per design we have select the simple roller chain.

Braking load = 42.30 KN

Pitch circle diameter of the gear or sprocket

$$D = P \operatorname{cosec} \left( \frac{180}{T} \right) = 25.4 \times \operatorname{cosec} \left( \frac{180}{31} \right) = 251.06 \text{ mm} = 0.2510 \text{ m}$$

Pitch line velocity,  $V = \frac{\pi d N}{60} = \frac{\pi \times 0.25 \times 109.135}{60} = 1.4342 \text{ m/s}$

Load on the chain =  $\frac{6.075}{1.4342} = 4.2358 \text{ kN} = 4235.8109 \text{ N}$

Centre distance between the gear,  $C_d = 30 \times P$

(For best result, the minimum centredistance should be 30 to 50 times the pitch)

$$= 30 \times 25.40$$

$$= 762 \text{ mm}$$

Correct centre distance,  $C_d = (762 - x) = (762 - 4) = 758 \text{ mm}$  ( $x$  should be within the range 2 to 5 mm)

$$\begin{aligned} \text{No. of chain links, } K &= \frac{T_1 + T_2}{2} + \frac{2X}{P} + \left[ \frac{T_1 - T_2}{2\pi} \right]^2 \times \frac{P}{X} \\ &= \frac{31 + 31}{2} + \frac{2 \times 758}{25.4} + \left[ \frac{31 - 31}{2\pi} \right]^2 \times \frac{25.4}{758} \\ &= 90.6850 \end{aligned}$$

Length of the chain  $L = K \times P = 90.685 \times 25.4 = 2303.4 \text{ mm} = 2.3030 \text{ m}$

### 2.1.8. Gear

As per design consideration we have chosen spur gear.

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Circular pitch,  $P = \frac{\pi d}{z} = \frac{\pi \times 251.06}{31} = 25.44 \text{ mm}$ ,  
 Diametral pitch,  $p = \frac{z}{d} = \frac{31}{251.06} = 0.1234 \text{ mm}$   
 Module,  $m = \frac{d}{z} = \frac{251.06}{31} = 8 \text{ mm}$ ,  
 Addendum,  $h_a = m = 8 \text{ mm}$ ,  
 Dedendum,  $h_f = 1.25 \times 8 = 10 \text{ mm}$   
 Depth of tooth,  $h = 2.25$ ,  
 Clearance,  $C = 0.25 \times m = 0.25 \times 8 = 2 \text{ mm}$   
 Working Depth,  $h_w = 2 \times m = 2 \times 8 = 16 \text{ mm}$ ,  
 Tooth Space,  $e = 12.56 \text{ mm}$   
 Tip diameter,  $d_a = m(z + 2) = 8 \times (31 + 2) = 264 \text{ mm}$ ,  
 Pressure angle =  $20^\circ$   
 Root diameter,  $d_f = m(z - 2.5) = 8 \times (31 - 2.5) = 228 \text{ mm}$   
 Tooth thickness,  $S = \frac{\pi \times m}{2} = \frac{\pi \times 8}{2} = 12.56 \text{ mm}$ ,  
 Fillet radius,  $r = (0.375 \times m) = (0.375 \times 8) = 3 \text{ mm}$

## 2.1.9. Selection of Bearing

**Bearing:** A bearing is a machine element which supports another moving machine element. It permits a relative motion between the contact surfaces of the members, while carrying the load. A cylindrical roller bearing is selected because it is suitable for high speed service and heavy radial and impact load.

$$d = \text{Internal diameter of roller} = 40 \text{ mm},$$

$$D = \text{Outer diameter of roller} = 68 \text{ mm}$$

$$B = \text{Breadth of roller} = 15 \text{ mm}$$

## 2.1.10. Selection of Fan

Fan and blower is a machine whose primary function is to provide a large flow of air for a specific purpose. This is achieved by rotating a number of blades connected to a hub and shaft which has to be driven by a motor. Air is forced through a cylindrical channel to separate light weight (specified material) materials from the waste. The force to be delivered by the air fan should be moderate so that it only overcomes the weight of the light material and must not disturb the heavier material. The average mass per unit area of the materials is assumed to be  $500 \text{ g/m}^2$  [3]. The weight of the material is

$$W = (m \times A) \times g, \quad \text{where, } m = \text{the mass per unit area of the materials}$$

$$W = 0.05 \times 0.12 \times 0.15 \times 9.81 \quad A = \text{the cross sectional area of the channel.}$$

$$= 0.0883 \text{ N}$$

So a minimum of  $0.0277 \text{ N}$  of force must be delivered by the air fan/blower.

Assuming an initial velocity of zero in the direction of flow. The rate of change in momentum

$$F = m \Delta v = \rho_a A v \Delta v = \rho_a A v^2$$

To evaluate the minimum required velocity of flow,  $V = \sqrt{\frac{F}{\rho_a A}} = \sqrt{\frac{0.0883}{1.225 \times 0.18}} = 0.2005 \text{ m/s}$

Where  $\rho_a$  is the density of air assumed to be  $1.2250 \text{ kg/m}^3$ .  $F$  is assumed to be the weight of the light material. So, the required volumetric flow rate =  $Av = 0.18 \times 0.2005 = 0.0361 \text{ m}^3/\text{s}$ .

Hence, an air blower of volumetric flow rate  $0.1450 \text{ m}^3/\text{s}$  is selected for the purpose which is higher than calculated and also based on the market availability of blowers.

## 2.2. Machine Description:

The municipal dry waste segregating machine consists of a hopper, a conveyor belt, an air blower, v-belt, magnetic pulley and a roller conveyor.

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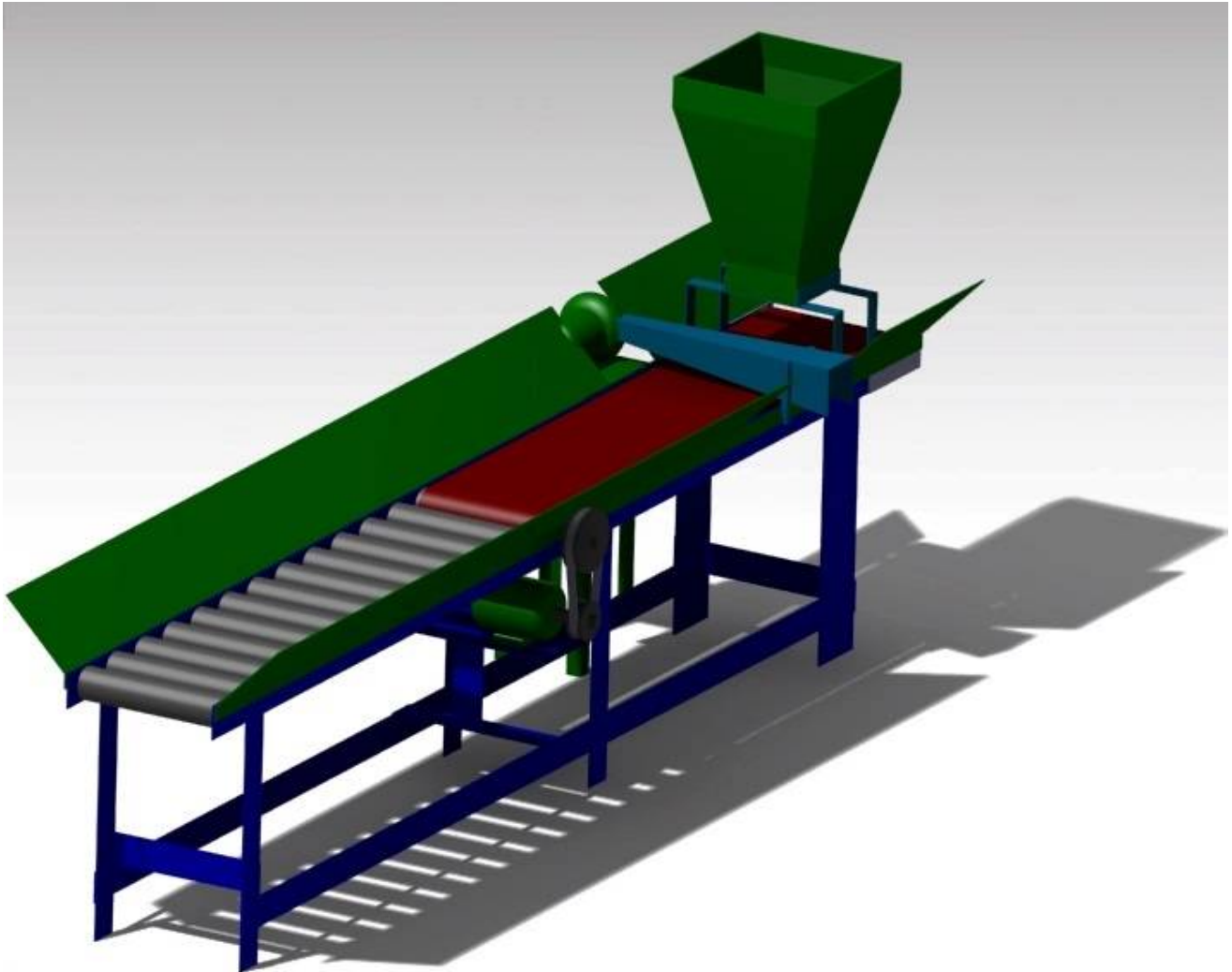


Fig-1: Municipal dry waste segregating machine.

A motor is used to run the entire machine. The rotational motion of the motor shaft is transmitted to the magnetic roller through the v-belt. This magnetic roller acts as the driver for the machine. Due to the rotation of this magnetic roller the conveyor belt also rotates and at the same time the magnetic roller is connected to the roller conveyor through the chain which is mounted over the gear and hence rotate the roller conveyor also rotates.

The mixed waste matrix is fed through the hopper and the conveyor belt carries the waste matrix. An air blower and the air channel mounted on the conveyor belt separate the light waste materials like plastic, polythene bags etc. from the waste matrix and are collected in collector bin-1. The left over waste matrix is carried away at the extreme end of the conveyor belt towards the magnetic pulley. Due to the magnetic attraction, the ferrous materials get segregated from the waste matrix and is collected at the bin-2. Then, the rest of the waste matrix automatically travel over the roller conveyor which separates the left over waste matrix in accordance with sizes. The bottles, paper, wood, cartons etc. of relatively smaller in size are sorted through the gaps between the roller and so collected at the bin-3 and then finally the remaining wastes of bigger sizes are collected at bin-4 at the end.



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## III. CONCLUSION

The study is based on the design of a municipal domestic dry waste sorting machine which can reduce human effort in the segregation of wastes and also which can segregate the disposal of wastes into a various components which can be recycle or use for some other useful purpose The operation of the machine is easy to understand and it may replace manual method of sorting waste. Hence, a municipal dry waste segregating machine has been successfully designed.

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