CHAPTER THREE

3.0 PROJECT METHODOLOGY

It details the selection of materials, machine components, design principles, and engineering calculations employed to ensure functionality, efficiency, and safety. The focus is on a shredding-type recycling system that transforms fabric waste into shredded material suitable for reuse.

3.1 Materials Selection

The selection of materials for fabrication of a Portable Fabric Recycling Machine is crucial to ensure the durability, performance, safety, and cost-effectiveness of the portable fabric recycling machine. The materials were chosen based on mechanical properties such as tensile strength, toughness, wear resistance, corrosion resistance, ease of fabrication, and availability in the local market. The materials selected are as follows for each component's parts of the machine.

- Frame: Mild steel (angle iron)
- Blades: Hardened carbon steel
- Motor: 1 HP electric motor
- Bearings: Pillow block bearings
- Belt and pulley system for power transmission

Table 3.1 Detailed Material Selection of the Machine Components

S/N	Component	Material Selected	Reasons for Selection
1	**Machine Frame**	Mild Steel (Angle Iron)	High structural strength, weldable, cost-effective, widely available
2	**Shredding Blades**	High Carbon Tool Steel	High hardness, excellent wear resistance, retains sharp edges
3	**Rotating Shaft**	Medium Carbon Steel	Good torsional strength, machinability, affordable
4	**Hopper and covers**	Galvanized Mild Steel Sheet	Corrosion-resistant, lightweight, easy to fabricate
5	**Motor Mount Base**	Mild Steel Plate (5 mm)	Strong and rigid to support motor vibration and weight
6	**Bearings**	Chrome Steel (Standard Ball Bearings)	Low friction, supports rotational loads efficiently
7	**Pulley System**	Cast Aluminum Alloy	Lightweight, corrosion-resistant, good mechanical properties
8	**Belt**	Neoprene Rubber (V-Belt)	High flexibility, good grip, long life span
9	**Output Tray**	Plastic/Aluminum Sheet	Lightweight and corrosion-resistant for easy handling of shredded fabric
10	**Fasteners (bolts, nuts)**	Stainless Steel	Corrosion-resistant and strong for structural integrity
11	**Electrical Casing**	PVC or Bakelite	Electrical insulation, impact resistance

3.2 Machine Description

The machine consists of a rectangular frame, a feeding hopper, rotating blade assembly mounted on a shaft, and a 1HP motor that drives the shaft via a pulley-belt system. The shredded fabric exits into a collection bin. Safety covers and emergency stop features are included for operator protection.

3.3 Materials and Component Used

The components parts of the machine, material used and reason for selection of each material were listed in Table 3.2 below:

Table 3.2 Materials and Components Used

S/N	Component	Material	Reason for Selection
1	Frame	Mild Steel (Angle Iron)	Good strength, weldability, cost-effective
2	Shaft	Medium Carbon Steel	High torsional strength, machinable
3	Shredding Blades	Hardened Tool Steel	Wear resistance, edge retention
4	Hopper	Galvanized Sheet Metal	Corrosion resistance, lightweight
5	Motor (1 HP, 1440 RPM)	Electric AC Motor	Sufficient torque for fabric shredding
6	Bearings	Deep Groove Ball Bearing	For smooth shaft rotation
7	Pulley and Belt System	Cast Aluminum + V-Belt	Power transmission, speed reduction
8	Output Bin	Plastic/Metal Tray	Lightweight, easy removal of shredded material

3.4 Design Considerations

The following parameters are considered during the design stage of the machine components. It includes: Blade type and geometry for clean cutting; Torque and power required for cutting fabrics; Rotational speed for efficient shredding; Structural integrity of the frame; Safety and operator ergonomics and Portability and ease of maintenance

3.5 Design Calculations

3.5.1 Torque Required (T)

Estimated force to shred medium-weight fabric = 80 N based on empirical cutting tests)

Effective radius of blade = 0.075 m

$T=F \times r$ (Kuznetsov and Severina, 2012)

$= 80\ \mathrm{N} \times 0.075\ \mathrm{m} = 6\ \mathrm{Nm}$

According to (Bhandari, 2010) ,adding safety factor of 2:

$T_{design} = 6 \times 2 = 12\ \mathrm{Nm}$

3.5.2 Power Requirement (P)

Given:

- Torque
- Angular velocity
- Torque $T=12$ Nm
- Angular velocity $\omega=2\pi N/60$

where N=1440 RPMN

$\omega=2\pi\times1440/60=150.8$ rad/s

$P= T \times \omega= 12\times150.8 =1809.6$ W

≈1.81 kW

Since this exceeds 1 HP, we use belt speed reduction to lower blade speed and torque requirement. Final selected motor: 1 HP (0.75 kW) with a pulley ratio of 2:1, which reduces shaft RPM to 720 RPM, making it sufficient for shredding after mechanical advantage (Khurmi & Gupta, 2005).

3.5.3 Blade Speed

Blade Revolution per minute RPM

=1440/2=720 RPM

This speed provides enough shear action for effective fabric shredding without overheating or jamming (Kuznetsov and Severina, 2012).

3.5.4 Shaft Diameter Design

Using maximum torque T=12 Nm, allowable shear stress for mild steel (Khurmi and Gupta, 2005).

T=12Nm,

Allowable shear stress for mild steel $\tau=40$ MPa

Torsion formula:

$T = \pi/16 \times \tau d^3$ (Bhandari, 2010).

$d^3=16T/\pi\tau$

$d^3 = 16 \times 12 / \pi \times 40 \times 10^6$

$= 1.53 \times 10^{-6}$

$d = 0.0117 \text{ m} \approx 12 \text{ mm}$

Selected shaft diameter = **20 mm** (for added safety and load-bearing) (Bhandari, 2010).

3.5.5 Frame Strength Check

Maximum load = 100 kg = 981 N

Cross-section of frame = 40 mm × 40 mm mild steel angle (Bhandari, 2010).

Yield strength of mild steel = 250 MPa (Khurmi and Gupta, 2005)

Allowable stress = 140 MPa (with safety factor)

Stress:

$\sigma = F/A = 981/(40 \times 2 \times 3)$

$= 4.09 \text{ MPa}$

3.6 Blade Design

- Material: Tool steel (HRC ~60)
- Blade thickness: 8 mm
- Blade length: 100 mm
- Cutting force (empirical): 80 N per fabric strip
- Number of blades per shaft: 4

3.6.1 Shear Force on Blade:

Let's assume the blade shears fabric across its width.

T = F/A = 80/(100×8)=0.1 MPa

Tool steel shear strength ≈ 600 MPa, Safe according **to** Khurmi and Gupta (2005)

3.6.2. Shaft Design (Torsion)

Torque T=12 Nm

Allowable shear stress, τ = 40 MPa (for mild steel)

$T = \pi\tau d^3/16$ (Bhandari , 2010)

$d^3 = 16T/\pi\tau$

$d^3 = 16\times12/\pi\times40\times10^6$

$= 1.53\times10-6$

$d \approx 0.0117$ m ≈ 12 mm

Selected shaft diameter = 20 mm (with SF = 2)

3.6.3. Pulley and Belt System

- Motor RPM = 1440
- Desired shaft RPM = 720
- Pulley ratio = 14407/20=2:1

If motor pulley diameter = 100 mm, then driven pulley = 200 mm.

3.6.3.1 Belt Length:

$L=2C+\pi/2(D + d) + (D-d)^{2/}/4C$ (Khurmi and Gupta ,2005); (Shigley ,2004)

Where:

- C = 300mm (centre distance)
- D = 200mm, d=100 mm, d =100mm

$L= 600+3.142/(300)+100^2/1200$

$\approx 600+471+8.3=1079.3$ mm3

Belt Length = ~1080 mm

3.6.4 Bearing Selection

Load on shaft = ~100 N

Required life: 3 years at 4 hrs/day = ~4000 hrs

Shaft RPM = 720

Dynamic Load Rating:

$L_{10}=(C/P^{)3}\times 10^6$ Shigley and Mischke (2004)

$C = P \times (L_{10}/10^6)^{1/3}$

$P = 100$ N, $L_{10}= 720\times 4000\times 60 =1.73\times 10^8$ rev

$C = 100 \times (1.73\times 10^8/10^6)^{1/3} \approx 100 \times (173)1/3\approx 100\times 5.55=555$ N

Select ball bearing with dynamic rating ≥ 600 N

3.6.5 Hopper Design

- Hopper height = 300 mm
- Top opening: 250 mm × 250 mm
- Bottom discharge: 100 mm × 100 mm

Volume:

$V=1/3\times h\times(A_1+\sqrt{A1\cdot A2}+A_2)$ (Bhandari 2010)

A_1 = 250×250=62500 mm2, A_2=10000 mm^2

$V=1/3\times300\times(62500+25000+10000) = 1/3\times300\times97500=9{,}750{,}000\ mm^3=9.75$ litres

3.6.6. Frame Design

The total weight on frame = 60 kg → Load = 600 N

Material: Mild steel angle iron (40×40×4 mm)

Allowable stress = 140 MPa

Stress check:

$\sigma = FA$

$= 60040 \times 4$

$=3.75\ MPa \ll 140\ MPa$

Frame is structurally safe.

3.7 Material Specifications (Sample)

3.7.1 Mild Steel (Frame Material):

- Yield Strength: 250 MPa
- Density: 7850 kg/m^3
- Welding and cutting friendly

3.7.2 Tool Steel (Blade Material):

- Hardness: ~60 HRC
- Tensile Strength: ~800–1000 MPa
- Heat-treatable for edge retention

3.7.3 Medium Carbon Steel (Shaft):

Tensile Strength: ~600 MPa

Torsional Strength: Medium to High

Machinability is Good

3.7.4 Aluminum Alloy (Pulley):

Density: 2700 kg/m^3

Non-rusting, good for moving parts