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Design & Development of Multipurpose Waste Recycling Equipment

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Abstract: The challenge of disposal and handling of solid waste is still one of the major problems in modern societies even though significant efforts are taken towards reduce, reuse, and recycling of waste. Large amounts of solid waste are getting piled up every day in almost every city across globe which is incrementing the amounts of pollution. Hence to cope up to this problem various reforms are being taken Multipurpose waste recycling unit majorly processes three types of waste that is fabrics, plastic and biodegradable/agricultural wastes in an efficient manner. Plastic is one of the majorly used material in the world, the recycling helps to recovers the material in the form of flakes and small particles. The fabrics and biodegradable wastes are similarly recovered in the form of the small flakes which can be further utilized. To realize the concept designed in this study, the method of shredding is used to convert the waste into fine compound and flakes. The multipurpose waste recycling equipment stands as a promising contribution to addressing the pressing need for enhanced recycling capabilities and promoting environmental sustainability through resource conservation.
Keywords: Waste recycling equipment, environmental waste management, plastic waste, Shredding, flakes.

I. INTRODUCTION

The increasing volume and diversity of waste pose a significant environmental challenge, necessitating advanced and versatile waste recycling solutions. The insufficient methods in processing different kinds of waste materials results in resource depletion and environmental harm. A multifunctional waste recycling machine with shredding technology is needed to improve recycling yield, lessen environmental damage, and advance environmentally friendly waste management techniques. By creating a whole system that can efficiently handle waste products, this project seeks to address these issues. The equipment prioritises to make the recycling equipment available in miniature version compared to large scale commodities. The imperative to improve recycling efficiency, lessen environmental effect, and advance sustainable waste management methods gives rise for a multipurpose waste recycling equipment. The shaft and blades are the shredder machine's crucial components that determine performance. It was discovered that the geometry and orientation of the blades installed in the single or double-shafts had a direct impact on the shredding efficiency. In order to fill in the research gaps regarding the shredder machine for waste materials, we are reviewing the different blade geometries and orientations that directly affect shredding performance. In order to meet these issues, this project will design and implement processing a variety of waste materials efficiently.

II. RELATED WORK

Mohit Waghmare ,Dnyaneshwar Nasane [1] developed design of a shredding machine which would help to shred the used betel nut leaves and coconut waste and would thereby help in waste management and disposal. J H Wong, M J H Gan [2] explained the evolution of the shredding in the six generation, about earlier days and progression alongside the exponential use of the shredder in various industries uses. Kikuchi R Jan K, Raschman R [3] described the various form of plastic waste available in the current situation. The basis of the segregation of the plastics on the content of chlorine contained is given. From which the size feasible for the shredding in small size shredder can be determined. Puttaraj MH, Shanmukha S [4] designed and developed the equipment for the making of the plastic bricks from the pellet of the plastics (2mm) through the process of moulding and the application of the heat. Dr Muhammad Maqbool Sadiq, Muhammad Rafique Khattak [5] describes the term solid waste and form of the mixed waste available due to unconditional export of waste from industries. The adverse effect on the environment are described as well as the present technology present in the market for waste management. Shilpi S, Monika S [6] researched the various technologies present to process the PET plastic bottles from manufacturing to the various process to recycle the plastic such as shredding, crushing, dissolution and depolymerization. Metin E, Erozturk A, Neyim C [7] conducted studies in turkey regarding the solid waste collected by municipal corporation and the amount of the waste that can be recycled without harming the environment.

Hrishikesh Suhas Bhagwat, Sarvesh Shailesh Sanap [8] researched about the present technology present in the market for the recycling the waste in major industries and problems while dealing with waste on the ground level. P Kumaran , N Lakshminarayanan [9] designed and developed the equipment for the segregation and recycling of the e-waste and the material requirements and ideal conditions according to the purpose of the waste to be recycled for the equipment are described using the model and simulation through CATIA. Vaibhav Edke, Swapnil Yemle [10] this paper described the manufacturing of the plastic shredding machine of 50×40×115 cm specification with the utilization of single shaft cutting blades with confetti cut shredder. Samuel Kofi Tulashie [11] This research investigates practice of turning plastic waste into paver bricks. showing the physical and chemical characteristics of plastic-sea sand blocks (PSPB) According to the research, mixing plastic trash with pavement blocks not only makes the blocks stronger and more lasting, but it also lowers the amount of plastic debris that ends up in the road. Atadious D. and Oyejide O. J [12] This study shows to manage plastic waste by designing and building a plastic shredder machine. With a shredding rate of 0.575 kg/s and an efficiency of 98.44% by the introduction of flywheel, the machine produced plastic fragments that ranged in size from 10 mm to 20 mm.

III. OBJECTIVE

1) To design and develop multipurpose waste recycling equipment
2) To manufacture the multipurpose waste recycling equipment at a minimum cost.
3) Study of elements of equipment such as blades, frame, belt-drives.
4) To develop products from the waste.
5) Portable and easy to use equipment.

IV. MATERIAL AND METHODS

A. Methodology

Following are schematics showing the methodology and planning used to approach for design and development of the final product

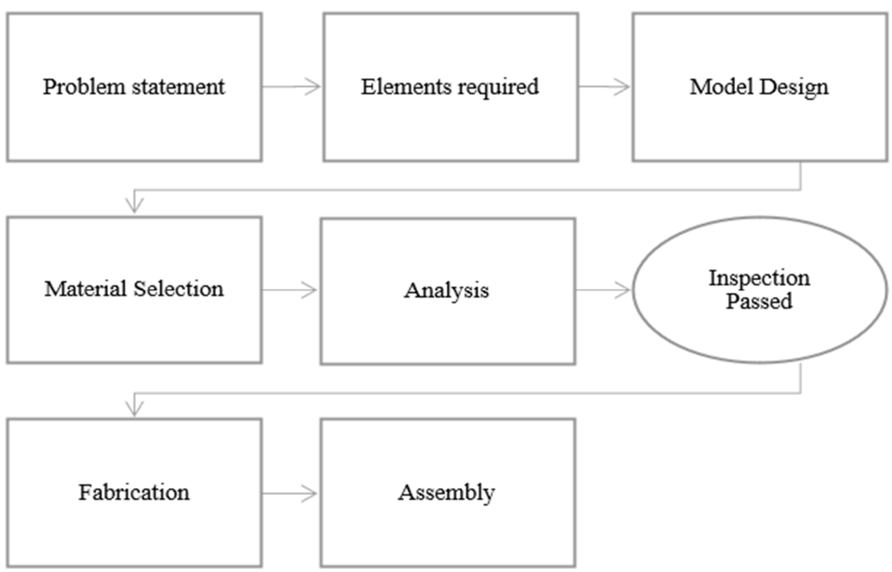

Fig.1. Flowchart of Methodology

B. Machine Description

The waste recycling equipment used in this project is made to apply a suitable amount of force to shred the plastic waste material by means of a cyclic impact loading. This gives the plastic material enough energy to cause its molecules to split or deform in relation to one another. The shredding chamber, shredding shaft, collector bin, hopper, and prime mover are the five essential components of this kind of equipment. An electric motor serves as the prime mover, producing the torque required to turn the shredding shaft. The component of the machine that feeds the waste plastic into the shredding chamber is called the hopper. There is blower installed that can separate light particles through separate vents. The shredded material is then extracted in container through the Helical screw conveyor.

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C. Material Selection Table

Sr no	Components	Material/Specification
1.	Hopper	Mild Steel
2.	Frame	2 inch Angle bar
3.	Shredding shaft and blades	AISI 1018
4.	Helical Screw Conveyor	AISI 1018
5.	Motor	2 Hp
6.	Belt	Aramind
7.	Bearing	Bearing no. 6204

Table 1. Material Selection Table

V. MODEL ILLUSTRATIONS AND DIAGRAMS

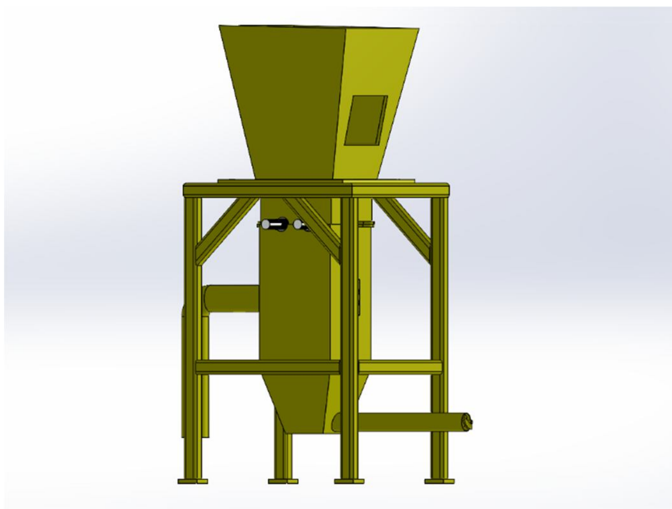

Fig.2. Assembly layout of equipment

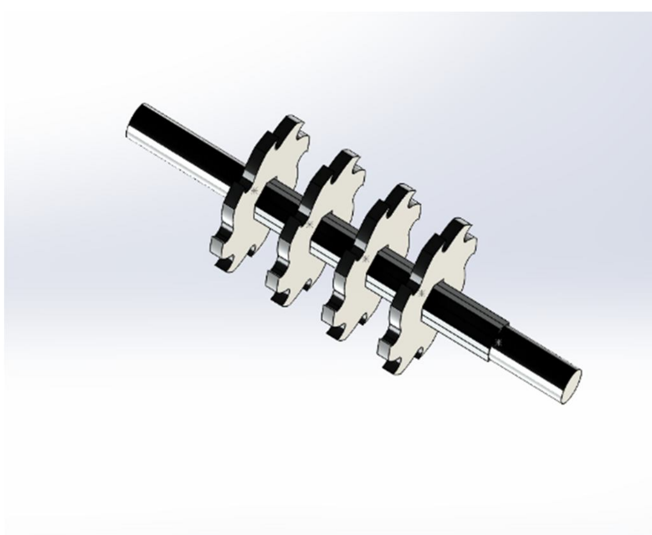

Fig.3. Blade Shaft assembly

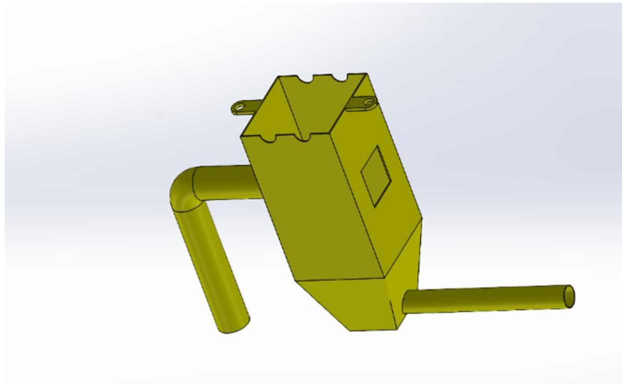

Fig.4. Midframe and conveyor assembly

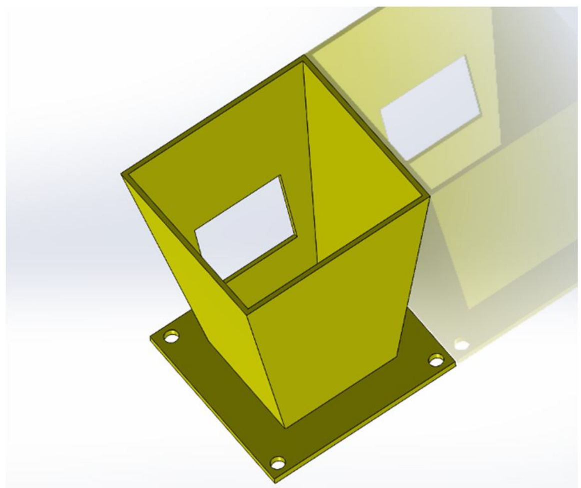

Fig.5. Hopper

VI. DESIGN CALCULATION

A. Helical Screw Conveyor

Flight Diameter (D)= 40mm
Flight thickness = 2mm
Pitch (p) = 40mm
Shaft diameter = 10 mm

1. Inner Length (l) = $\sqrt{(d\Pi^2) + P^2}$

$= \sqrt{(10\Pi^2) + 40^2}$

(l) = 50.86 mm

2. Outer Length (L) = $\sqrt{(D\Pi^2) + P^2}$

$= \sqrt{(40\Pi^2) + 40^2}$

(L) = 131.87 mm

3. Inner Radius of Blank (d') $= \frac{D-d}{(L/l)-1}$

$= \frac{40-10}{(131.87/50.86)-1}$

(d') = 18.83 mm

4. Outer Radius of the Blank (D') = (D-d) + d'

= (40-10) + 18.83

(D') = 48.83 mm

5. Cutting Angle of the Blank $D'(<°) = \frac{L}{(\frac{D'\Pi}{360^0})}$

$= \frac{131.87}{(\frac{48.83\Pi}{360^0})}$

$= \frac{131.87}{0.426}$

$D'(<°) = 309^0$

Hence, Cutting angle $= 360^0 - 309^0$

$= 51^0$

6. Load Capacity of Screw Conveyor (Q) $= 60 \times \frac{\Pi}{4} \times D^2 \times S \times N \times \phi \times \rho \times C$

$= 60 \times \frac{\Pi}{4} \times 40 \times 40 \times 20 \times 0.12 \times 1050 \times 1$

= 7.60 Kg/hr

Where, Q = screw capacity in kg/h
D = screw diameter in m
S = screw pitch in m
N = screw speed in rpm
ϕ = loading ratio
ρ = material loose density in kg/m3
c = Inclination error

B. *Cutting Blade*

Radius of Blade (Hexagonal Circle) = 60 mm
Width of cutting Blades (w) = 10 mm
The of material to be shredded is assumed to be overall (t) = 5mm

Cutting area of material (A) = w × t

$= 0.01 \times 5 \times 10^{-4}$

$= 5 \times 10^{-6} m^2$

where, w = Width of cutting blade
t = thickness of material

Breaking Strength of material (τ) = F.O.S × ultimate Strength
= 1.5 × 80
= 120 MPa

Cutting force (F) = $\tau * A$

$= 120 \times 10^6 * 5 \times 10^{-6}$

= 600 N

Torque blade = force × Radius of blade
= 2(5.75) × 60
=6.90 Nm

Torque shaft = Torque blade × Torque blade cut
= 6.90 × 8
= 55.2 Nm

Torque Drive Shaft = 2 × 55.2
= 110.4 Nm

Power needed = Torque Drive shaft × Revolution(rpm) × conversion factor
= 110.4 × 50 × (0.00014)
= 0.8 Hp

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C. Hopper

Volume of hopper $= \frac{h}{3} \times (A1 + A2 + \sqrt{A1 \times A2})$

A1=Area of top base = 40cm× 35cm

A2=Area of top base = 30cm× 25cm

h= 30cm

Volume of hopper $= \frac{30}{3} \times \left(1400 + 750 + \sqrt{1400 \times 750}\right)$

$= 0.0159\ cm^3$

VII. FEA ANALYSIS

A. Cutting blade

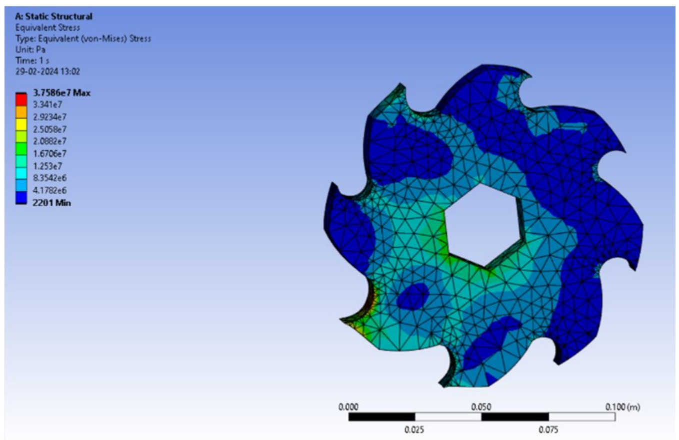

Fig.6. Total Deformation of the blades

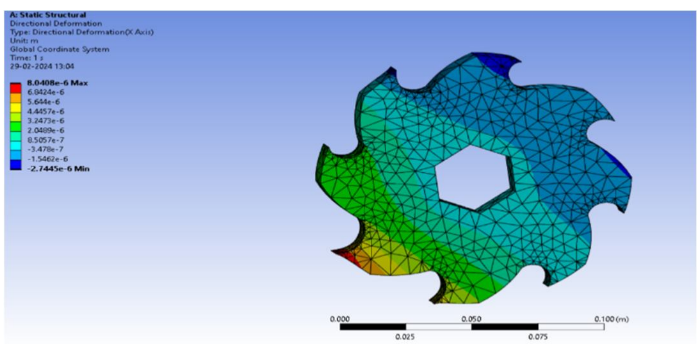

Fig.7. Directional deformation of the blades

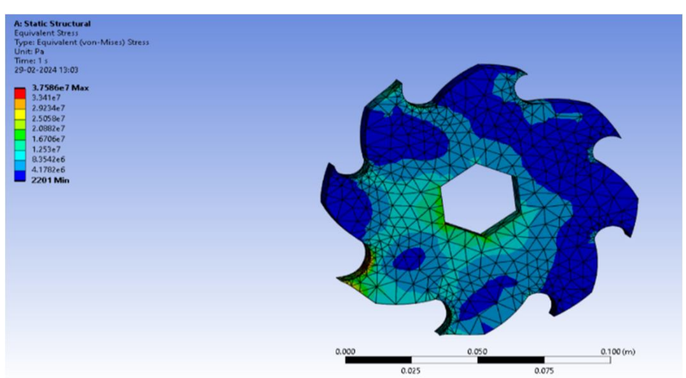

Fig.8. Equivalent stress on the blades

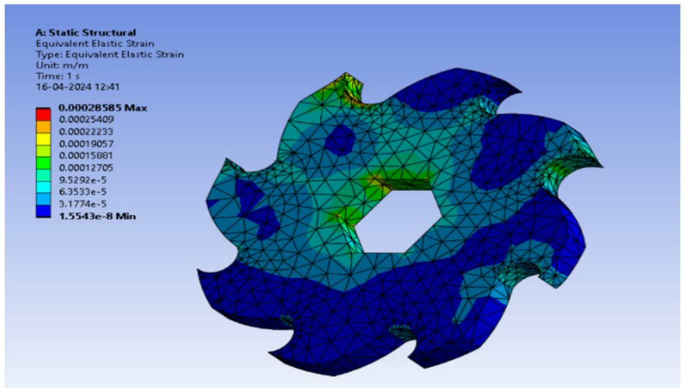

Fig.9. Equivalent Elastic strain on the blades

Sr No	Material	Rotational velocity	Load (N)	Total Deformation (cm)		Directional deformation (cm)		Equivalent stress (MPa)		Strain	
				Min	Max	Min	Max	Min	Max	Min	Max
1	AISI 1018	50	1000	0	0.0009	0	0.00078	0.02	37.5	9.92E-09	0.000184
		40	1500	0	0.0013	0	0.00117	0.031	56.6	1.52E-08	0.000187
2	Structural Steel	50	1000	0	0.00092	0	0.0008	0.022	37.7	1.10E-08	0.000189
		40	1500	0	0.00096	0	0.0024	0.036	58.7	1.68E-08	0.000286
3	AISI 1065	50	1000	0	0.00093	0	0.00068	0.02033	37.3	1.12E-08	0.000184
		40	1500	0	0.00138	0	0.0011	0.03108	54.6	1.56E-08	0.000283
4	ASTM A29	50	1000	0	0.0009	0	0.00074	0.0203	36.8	9.92E-09	0.000184
		40	1500	0	0.0012	0	0.00124	0.036	57.7	1.52E-08	0.000187
5	AISI 1020	50	1000	0	0.00093	0	0.0008	0.023	37.27	1.02E-08	0.000189
		40	1500	0	0.0014	0	0.00119	0.031	55.96	1.55E-08	0.000285
6	ASTM A510	50	1000	0	0.00089	0	0.00068	0.022	37.18	1.12E-08	0.000184
		40	1500	0	0.00138	0	0.00116	0.0305	56.85	1.56E-08	0.000283

Table.2. Analysis Reading of Cutting blade

B. *Helical Screw Conveyor*

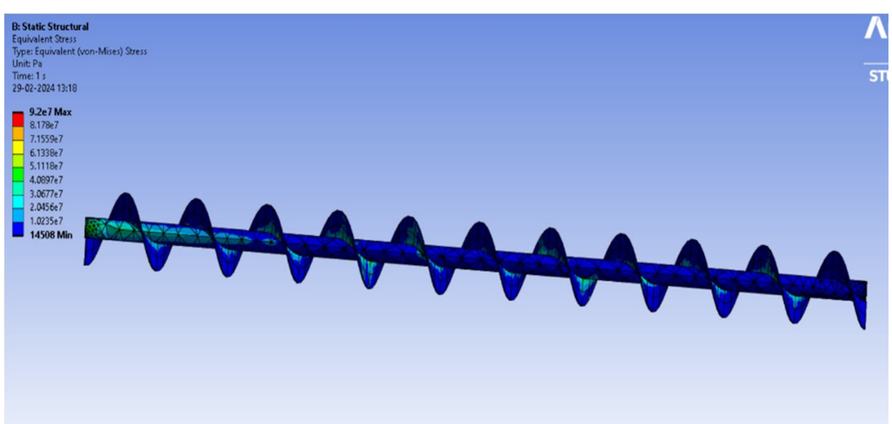

Fig.10. Total Deformation of the Screw Conveyor

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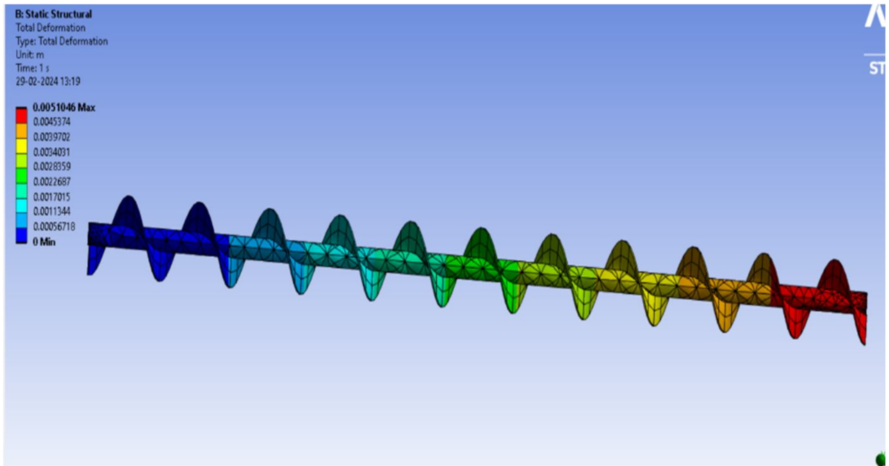

Fig.11. Directional Deformation of the Helical Screw Conveyor

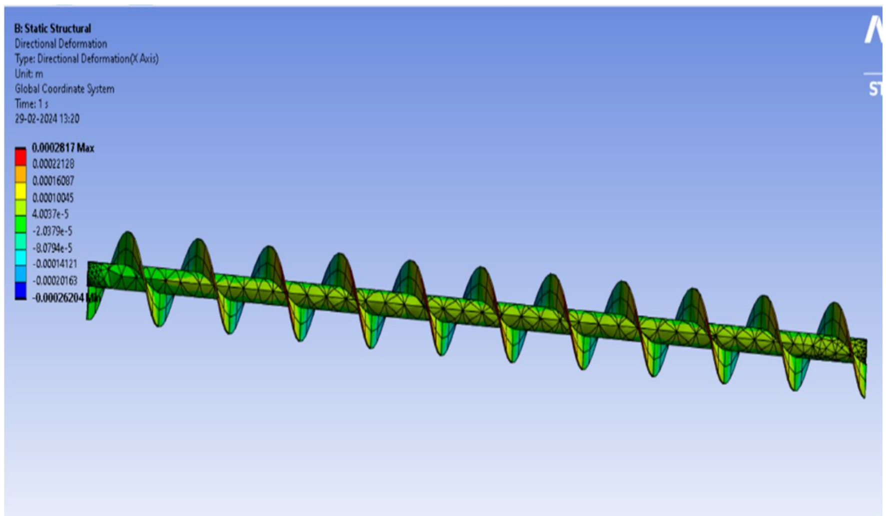

Fig.11. Equivalent Stress on the Screw Conveyor

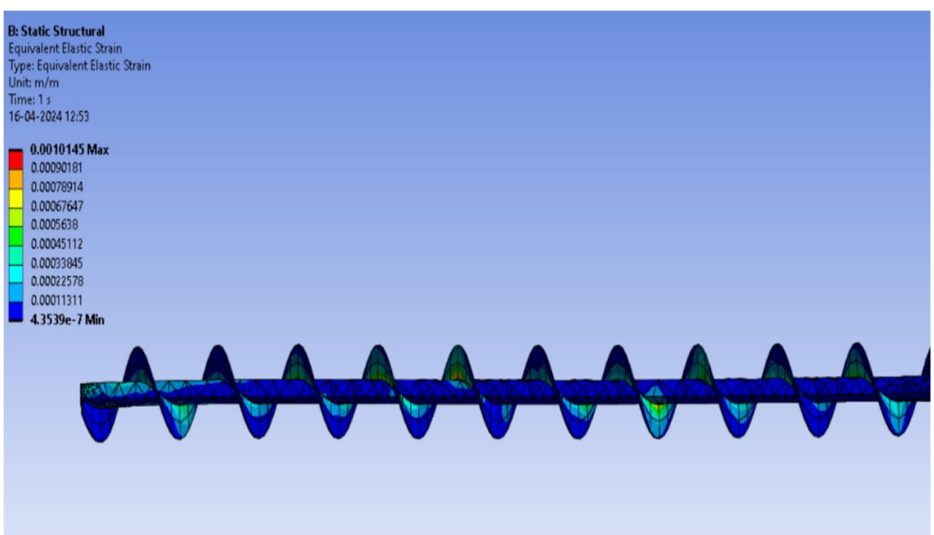

Fig. 12.Equivalent Elastic strain on the Screw Conveyor

Sr No	Material	Rotational velocity	Load (N)	Total Deformation (cm)		Directional deformation (cm)		Equivalent stress(Mpa)		Strain	
				Min	Max	Min	Max	Min	Max	Min	Max
1	AISI 1018	50	1000	0	0.498	0	0.0274	0.01364	91.24	1.05E-06	0.0002
		40	1500	0	0.63465	0	0.03789	0.0132	127.98	3.01E-06	0.00047
2	Structural Steel	50	1000	0	0.51401	0	0.0281	0.0145	92	3.84E-07	0.00072
		40	1500	0	0.7	0	0.0394	0.0136	128.2	4.39E-07	0.001
3	AISI 1065	50	1000	0	0.5028	0	0.0267	0.0142	92.8	3.82E-07	0.00073
		40	1500	0	0.656	0	0.0396	0.0134	128.86	4.36E-07	0.00101
4	ASTM A29	50	1000	0	0.5014	0	0.028	0.01374	91.76	1.05E-06	0.0002
		40	1500	0	0.6984	0	0.0378	0.0132	128.11	3.01E-06	0.00047
5	AISI 1020	50	1000	0	0.718	0	0.289	0.01475	92.45	3.84E-07	0.00073
		40	1500	0	0.524	0	0.0397	0.01376	128.77	4.35E-07	0.00101
6	ASTM A510	50	1000	0	0.5015	0	0.0264	0.0145	92.46	3.82E-07	0.00073
		40	1500	0	0.649	0	0.0389	0.01329	128.77	4.36E-07	0.00101

Table.3. Analysis Reading of Helical Screw Conveyor

VIII. RESULT AND DISCUSSION

In the article, a study was performed on the waste recycling equipment that will have a sustainability in time with the role that it is performing. With this, the task of reducing pollution by waste would be fulfilled, since it would fulfill its main role which is to obtain recycled material in form of small waste particles. Inside the shredding module, shredding is done by the blades on the shaft. The container is present where the small parts of the plastic shredded by the blades is accumulated. The design of the plastic waste shredding machine could be used to recycle the textile which can be reused or made into aesthetics product, whereas biodegradable waste can be shredded to make compost and the plastics(PET) is shredded to be recycled suitable for ingenious purposes After analysing considering the different material under various conditions the AISI 1018 is found to be optimum for this purpose. AISI 1018 is a commonly used low-carbon steel known for its excellent weldability, machinability, and relatively low cost.

A. Properties

Density: 7.87 g/cm³.
Modulus of Elasticity (Young's Modulus): Approximately 205 GPa.
Poisson's Ratio: 0.29.
Yield Strength: 370 MPa.
Ultimate Tensile Strength:440 MPa.
Elongation at Break: Typically around 15% to 20%.

IX. CONCLUSION

Our goal with this project was to design and develop, inexpensive equipment that could be versatile as well as economical as compared to other method of recycling. The waste recycling machine is widely utilized in large industries for the waste management. So to cope up with the waste at domestic level there is need of recycling equipment available in miniature form. By using this waste recycling machine the general costing of recycling process get reduced, it require less labor work and there's no requirement of skilled labor . In recycling process of waste requires low energy thanks to compact sort of waste it reduces the process time. Through this project we can realize the importance of this equipment for what purpose they serve, realize that the work can get done faster and more efficiently. The use of this machinery is critical for environment in future where the utilization of the resources increases with the ever increasing population the reduction of the waste and its indirect pollution has major impact. This project is still in its early stages, nonetheless. It is possible to increase the capabilities and optimize its performance through more research and development.

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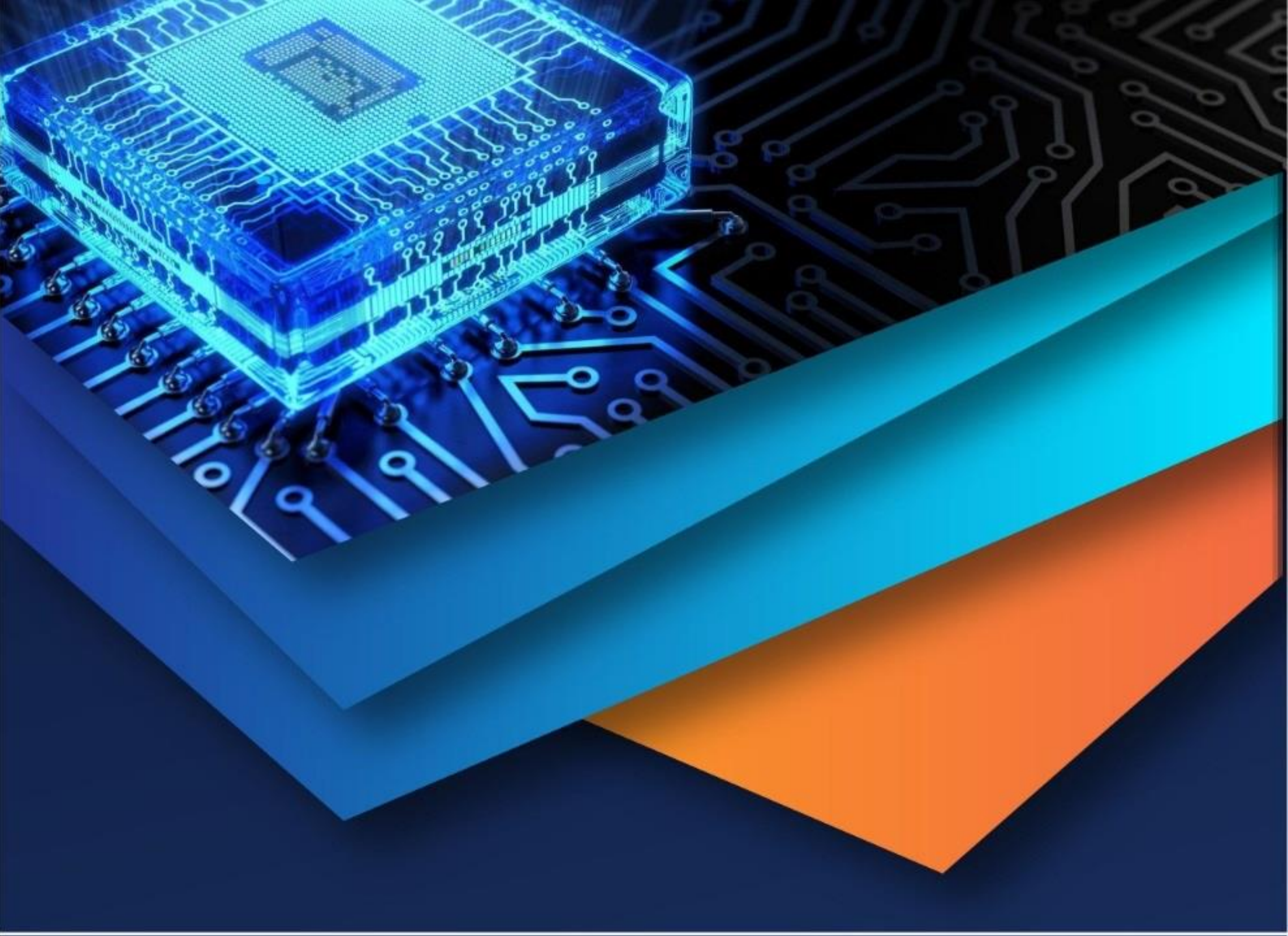

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