Design and Fabrication of Portable Plastic Shredding Machine

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***Abstract-* Plastic shredding machines are coming into picture for post processing of plastics like PET, PPE and PVC etc. Plastic shredders traditionally have a lot of drawbacks and a serious changeover was necessary. The factors such as cost, efficiency of power utilization, portability, efficient design and methodology, etc. all these are taken into account and successfully been tried to minimize through our model. Portable (As per industrial standards) Plastic Shredders will help to minimize the problems faced by such traditional heavy shredders. This paper discusses the design of a 5HP Portable plastic shredder which will be useful for Waste management in Industrial as well as localities to dispose of thermoplastics by converting them into flakes, which can be further reused for variety of applications.**

I. INTRODUCTION

Plastic Recycling is an important issue in today's society and one that has gradually gained momentum over the years as wastes and threats to the environment and human health have grown. As technology develops, the amount of materials that can be reused or recycled also grows. Given current population trends and the amount of wastes that will be produced, recycling and reuse needs to take a front seat in our everyday lives.

We can primarily focus on the packaging industry and how that relates to recycling. Since plastics are so prevalent in the packaging/consumer industry they will have an effect on recycling rates. The increase in plastics may pose serious problems for waste disposal operations, which are almost all managed by local governments. As landfill space diminishes and as new landfills are becoming nearly impossible to site, solid-waste planners must look to other methods of waste management.

II. SIGNIFICANCE OF STUDY

Majority of plastics recycling machine are imported and costly, hence there is need to locally develop a recycling machine from locally sourced materials to make their fabrication cheaper. After Studying various machines, we found out that they were build up for large scale industries which occupies a lot of space and energy. We are trying to develop something which can be portable as well as useful for small scale industries, Recycling Plants, Small Societies, Municipal Dump Grounds etc. Also these machines are too much costly and heavy. The overall survey helped us decide our current design and product. So, we are currently trying to build the first prototype product which will satisfy all the needs.

III. DESCRIPTION AND OPERATION OF SHREDDER

The Plastic shredder designed should be Portable; hence we initially selected the dimensions of setup i.e. capacity of approximately 2 PET bottles at a time, as PET is our main focus for shredding.The shredding box consists of 2 hexagonal shafts which will mount 12 and 13 blades on each. Along with spaces provided between them.The blades are having 3 tips hardened for cutting action.They are produced as a tri hawk claw pattern.The bearings provide support to shafts press-fitted on bearing walls.The side walls have welded guide blades for uniform cutting action by blades and separation of flakes during operation.The motor is connected to one rotating shaft by connecting via gearbox via a flange coupling.Two spur gears are provided, one of which transmits equivalent torque to other corresponding shaft.

IV. DESIGN PROCEDURE

After analyzing all the properties, we decided not to work more on PP as it was tough and with not many of the applications which we were aiming for. We now focused more on the PET as it had a Ultimate Tensile Strength of around 80MPA. If we succeed in shredding the PET then other bottles will obviously shredded as they have less UTS values than PET. We studied various theories of failures; we were a bit more confused between the two namely Maximum Shear Stress Theory Distortion Energy Theory and Von Misses Theory.

Upon further studying we found out that the shredding actions is not a proper case of shear failure, its more of a combination of bending, compressive and shear failure. Keeping in mind this information, we decided to go with the Distortion Energy Theory or Von Misses Theory to find out the Stresses and forces which we need to apply to shred the plastic.

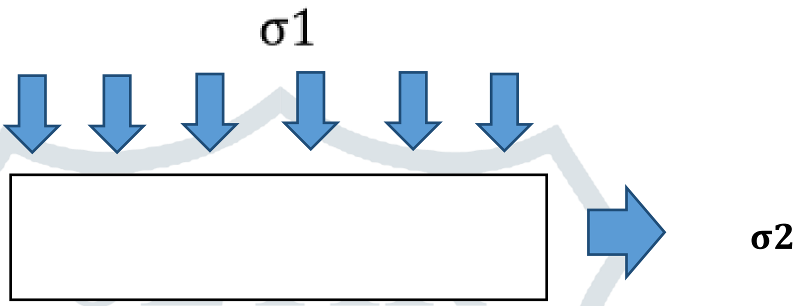

Figure 1 : Force Distribution

$$\sigma^2 = \left(\frac{1}{2}\right)\left[(\sigma 1-\sigma 2)^2+(\sigma 2-\sigma 3)^2+(\sigma 3-\sigma 1)^2\right]$$

Now we made certain assumptions that the stress acts along only 1 direction and hence equations changes to.

$$\sigma > \sigma sy$$

As we are dealing with the Plastic material, we consider Ultimate Tensile Strength for the calculations. Hence we consider the UTS of PET as 80Mpa for the calculations. So, if we apply a force greater than 80Mpa then surely we can cause the failure. Starting with the calculations,

$$\sigma = \frac{F}{A}$$

Now we studied various combinations of blades and found out that greater the blade contact area, greater is the force required to apply the Constant stress. We finally decided to go with the rectangular cross section of blade cutting area with the cross section of 100mm.

Therefore,

$$\sigma > 80\ Mpa$$

$$\sigma = \frac{F}{100(\mathrm{mm2})}$$

F > 80 x 100 N

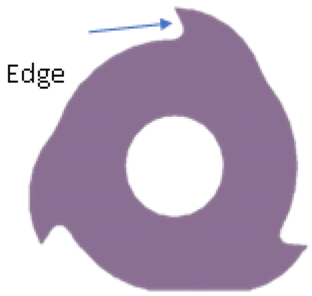

Figure 2: Blade Geometry

F >= 8000N

Power Calculations

Electric motors are usually chosen from the Power requirements and the Speed.

$$P = \frac{2 X \Pi X N X T}{60}$$

$$T = F X R$$

$$T = 8000 X \frac{5}{100}$$

$$P = \frac{2 X \Pi X 60 X 400}{60}$$

T = 400N-mP = 2513.27 Watt

P = 3.36 HP

Shaft calculations

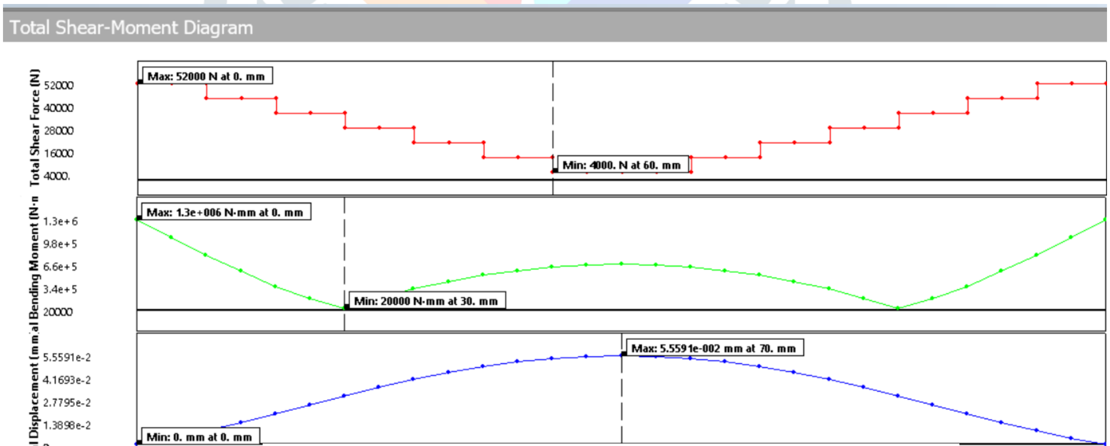

Figure 3 : Shear Force Diagram and Bending Moment Diagram

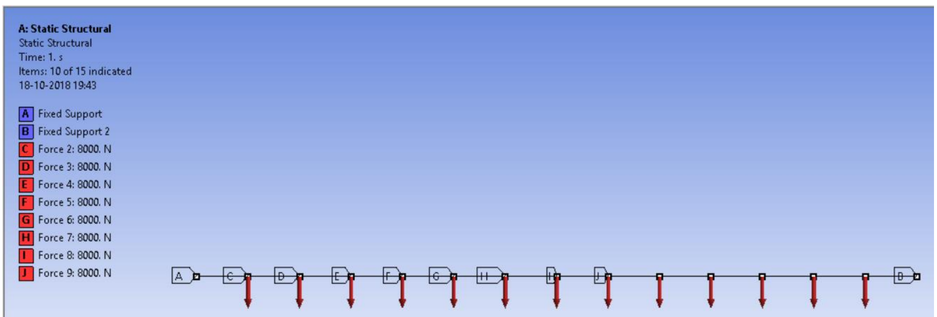

Figure 4: Force Application

Max Bending Moment (Mb) = 1.3 X 10^6 N-mm was recorded.

Max Torque of (T) = 0.4 X 10^6 Nm was recorder

Using Max Shear Stress Theory of Failure,

$$Te = ((M)^2 + (T)^2)^{0.5}$$

Te = 1.85 X 10⁶ N-mm

$$D^3 = \frac{(16\,X\,Te)}{\Pi\,X\,\tau}$$

Substituting in the above equation,

D=40mm

Bearing calculations

L10= 72 million revolutions

P =8000 N

C (dynamic loading capacity) = 33,281 N

V. ANALYSIS

A. Blade analysis

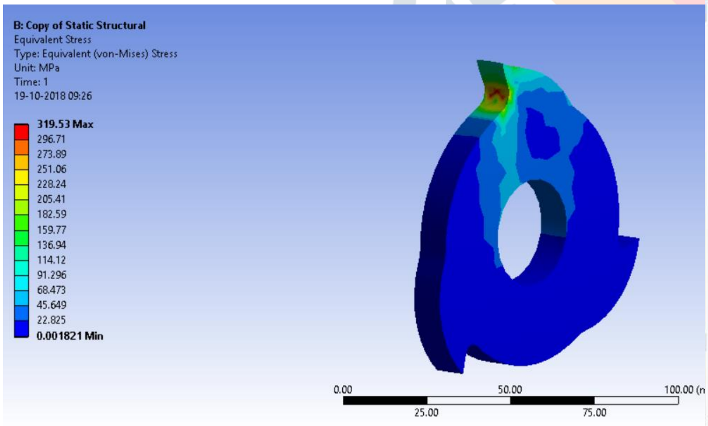

Figure 5: Final Product

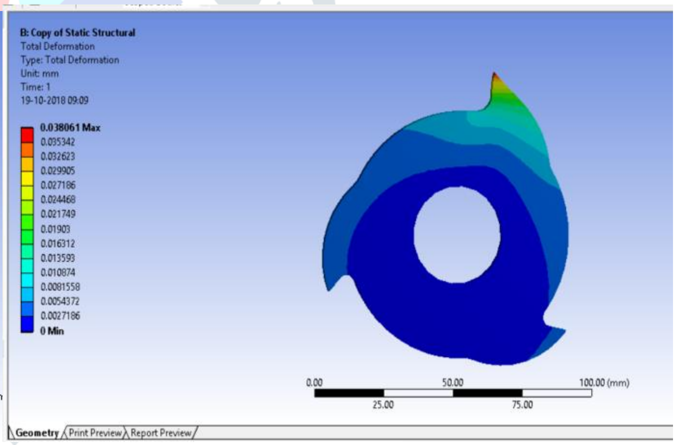

Figure 6: Final Product

By a detailed analysis of blades in Ansys Workbench,We applied a force of 10,000N on the blades and a fixed support on the inner sides of the blades where the shaft rest. We found out the following results, we had chosen structural steelas our blade material. The Von Misses Stress was found around 300 MPA, which was under the yield stress of steel.Steel. The highest stress was found out at theroot of the blades suggesting that we should gofor a neel was finalized as ext possible grade of steel in comparisonthe blade material with hardening at the blade surface to make it more tough and resistant to damage or scratches. Deformationof around 0.03mm was bearable and a FOS of around 1.5was observed.The Inner portions are not under any stress and we are going to optimize it in the later parts of the project.

Hence, Blade Design is SAFE!

B. Shaft Analysis

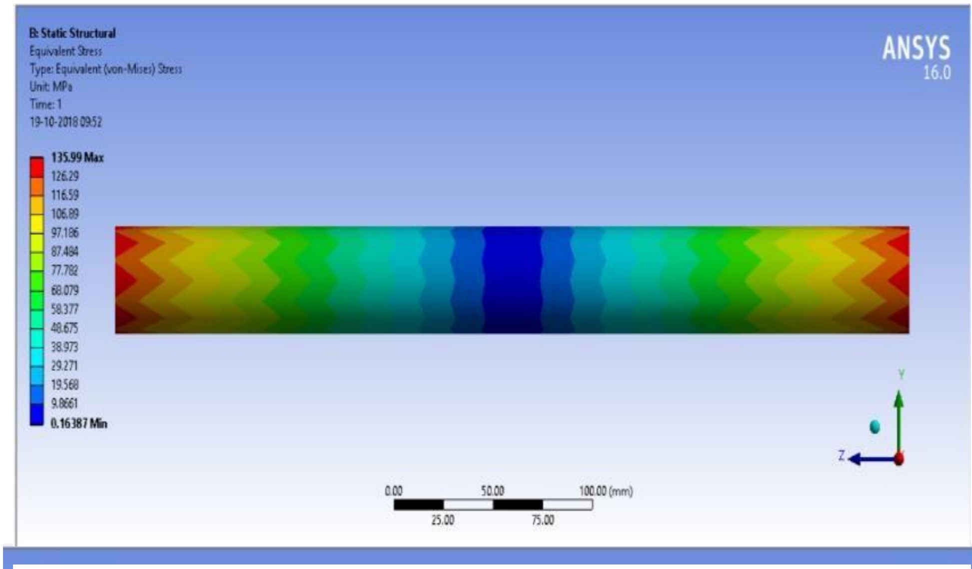

Figure 7: Shaft Equivalent Stress Von Mises)

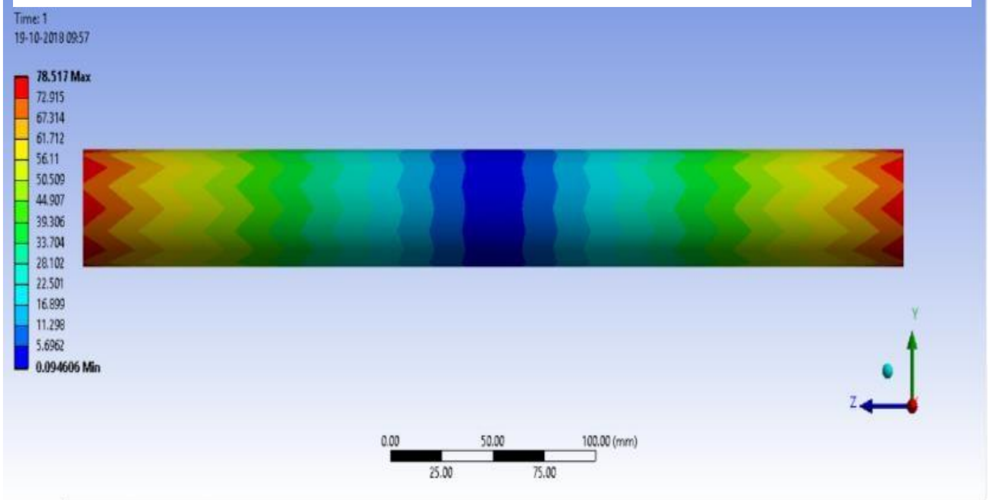

Figure 8: Max Shear Stress

Max Stress Using Von MissesLowest Factor of safety is 1.5,

Required force for failure is 135 Mpa, so Shaft is Safe.

Using the Max, Shear Stress Theory, and Max Stress is 78 MPA which is less than the Max Shear stress limit of Structural Steel.

So, The Design of Shaft is Safe!

VI. RESULT/SUMMARY

Component (quantity)	Quantity	Specification	Material/Make
Cutting Blade	26	OD=100mm, ID=41mm, b=5mm, t =10mm.	C-45
Shaft (Hexagonal)	2	OD=40mm, L=500mm.	C-45
Bearings	4	40 x 68 x 15 mm	6008/C3 SKF
Side wall	2	400 x 160 x 6mm	MS
Bearing wall	2	240 x 160 x 20mm	MS
Spacers	24	OD=55mm, ID=41mm	MS
Guiding Blades(26+26)	52	varied, t=2mm	MS
Key	2	12 x 8 mm	Woodruff
Bolts&nuts	12	Length = 50 mm	M10
Spur Gears	2	OD=80mm, ID=40, b=, m=8, z=10	C-45
Motor	1	5HP	Hindustan (3 phase,4 pole 5 HP,1440rpm)
Gearbox	1	25:1	Premium motor/Flange Mounted (25:1)

Table 1: Result Table

The fabricated material of shaft and blade prototypes is C45, but ideally it can be stainless steel as both have equivalent use according to required calculations.

1. The shaft can sustain up to 67million rev. as per dynamic loading capacity. Hence we can consider that the life of the shredder is 6 years. But for blades considering wear, the blades should be replaced after 1.5 year (according to industrial wear standards).
2. Thus the average life of the shredder must be 5 years considering FOS.
3. The total weight of the prototype is 70kg which can be reduced by using Stainless Steel(except for gearbox and motor).
4. The developed shredder has volume 400×240×160 mm^3.

VII. CONCLUSION

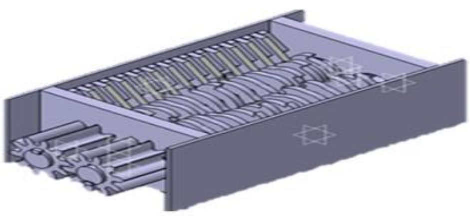

Figure 9: Final Product

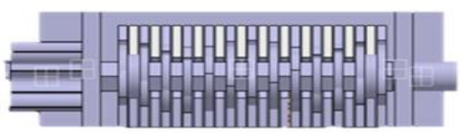

Figure 10: Final Product Cross Section View

1. Successful plastic waste management system can be set up.
2. This prototype is efficient on domestic as well as industrial scale (due to its compactness).
3. From the recycled thermoplastics 5mm to 7mm size flakes can be produced which can be further remolded and used for variety of applications.
4. The prototype has guaranteed safety for assembly and has has easy operation for usage.

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