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RESEARCH ARTICLE

A New Blade Design for Municipal Solid Waste Bag Opener Machines: A Static and Fatigue Finite Element Analysis Study

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ABSTRACT - Municipal solid waste (MSW) presents a global challenge, carrying health and environmental risks without proper recycling and disposal methods. Mechanical-biological treatment (MBT) emerges as a promising solution capable of recycling MSW and reducing landfill volumes. However, the efficiency of MBT heavily relies on the bag opener machine, which extracts waste from bags. Therefore, enhancing the bag opener machine's performance is crucial for optimizing the MBT process. This paper introduces four blade models (A, B, C, and D) with different cutting angles (60°, 50°, 45°, and 30°, respectively) aimed at achieving high efficiency, low power consumption, minimal maintenance costs, and extended service life. The blade design was developed using the 3-D modeling software, SOLIDWORKS. Additionally, the paper presents primary calculations of the bag opener machine, which were informed by a review of MSW characterization studies. Static and fatigue finite element analyses (FEAs) were conducted under a pressure of 1 MPa to assess blade strength, performance, and durability. The results indicate that the proposed design can handle a capacity of approximately 30 tons/hr with a power consumption of 22 kW. Notably, blade model D, featuring the minimum cutting angle of 30°, exhibits the lowest Von Mises maximum stress at 15.18 MPa and the minimum factor-of-safety (FOS) at 18.12. Fatigue stress analysis reveals a life expectancy of 10^6 cycles for all blade models. In conclusion, model D demonstrates superior strength, FOS, and durability, making it the optimal choice for the bag opener machine.

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1.0 INTRODUCTION

Municipal Solid Waste (MSW) includes non-hazardous materials like food residues, textiles, paper, and certain plastics [1],[2],[3]. Managing MSW effectively is a major challenge due to the complexities of its generation, treatment, and disposal. Demographic, economic, and social changes further complicate MSW management, adding pressure on waste service providers [4]. Mechanical waste treatment is a common method for extracting valuable components from waste streams through size reduction, separation, sorting, and recovery of materials and energy [5],[6],[7],[8],[9]. This method reduces landfill and incinerator use, increases recycling rates, produces refuse-derived fuel (RDF) or solid recovered fuel (SRF) from non-recyclable waste, and pre-treats the organic fraction for biological treatment [10]. An MSW bag opener, or pre-shredder, plays a critical role in mechanical waste treatment by breaking and emptying waste bags containing mixed materials [9]. It enhances the efficiency and quality of subsequent sorting and separation processes, improves the recovery and recycling of materials, reduces contamination and moisture in the organic fraction, and lowers operational and maintenance costs [10],[11],[12]. Characterizing MSW is crucial for designing bag openers, as waste composition affects the cutting blades' size, shape, material, speed, and power. Properties like bulk density, size distribution, and moisture content influence the wear and tear on blades, machine power consumption, and quality of shredded output [13],[14].

There are various types of MSW bag openers, such as single shaft and double shaft pre-shredders, each with distinct advantages in capacity, power consumption, maintenance cost, and efficiency [5], [15], [16]. Blade design is a key factor, significantly impacting the performance and efficiency of bag openers. Important considerations include the blades' shape, size, material, coating, and arrangement [17], [18],[19], [20]. Optimizing blade design is essential for high efficiency, low power consumption, low maintenance costs, and extended machine life [18],[19]. Different machines may feature unique blade designs to accommodate various waste bags and materials [17]. Shredder machines come in single shaft, double shaft, or four shaft types, each with specific benefits and drawbacks regarding capacity, power consumption, maintenance costs, and efficiency [21]. Their design and performance depend on input material, product shape, downstream processes, and operational conditions.

2.0 LITERATURE REVIEW

The literature review examines MSW management in Algeria, Morocco, and Egypt, noting a shift from uncontrolled dumping to sanitary landfills, indicating increased environmental awareness. It highlights the high proportion of organic waste in MSW, requiring specific treatment methods, and identifies a gap in research on MSW bag opener machines

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essential for shredding mixed waste. This review aims to inspire further research and innovation in MSW management for sustainability.

In Algeria, a study found that organic materials constitute 54% of the waste, followed by plastics (18%), paper and cardboard (8%), textiles (12%), glass (2%), metals (2%), and miscellaneous materials (4%) [22]. The shift from unauthorized dumping to regulated sanitary landfills reflects a growing commitment to environmental preservation and a systematic approach to MSW management. In Tangier, Morocco, a study using the MODECOM methodology reported that waste is mainly organic (53%) and recyclable (23%), highlighting the need for composting and sorting facilities [23]. The waste was sampled from three size fractions and 13 classes, collected from four habitat types and three socio-economic levels. In Egypt, a study in the villages of Qalamshah, Monshat Ramzy, and Abou Defeya found organic waste proportions of 76%, 67%, and 80%, respectively, excluding diapers, which constituted 9.3%, 14.3%, and 5.8% [24]. Another field study in four Egyptian governorates found that average waste production was 0.63-0.82 kg/day per person, primarily food (41-70%) and plastics (6-16%). Waste production was negatively correlated with family size and positively correlated with electricity use [23]. Another study revealed that MSW in Egypt comprises 56% organics, 13% plastics, 10% paper and cardboard, 4% glass, 2% metals, and 15% other materials, with significant variation across different governorates [25].

A study on direct shear and hydraulic conductivity of MSW and High Molecular Weight (HMW) combinations found a significant alteration in friction angle and hydraulic conductivity at an HMW content threshold of 40% [23]. Despite numerous investigations into shredder models, including counter-rotating twin-shaft shredders [26] and landfill compactor shredder attachments [27], there is a lack of research on MSW bag opener machines. Technical nuances such as the quantity of cutting edges, blade geometry, material, and coating influence shredder machines' functionality and longevity significantly. Research has analyzed and optimized these aspects using methodologies like blade reversing action [28], transient finite element analysis [29], and material selection and hardening processes [30]. However, these studies have not focused on the specific requirements of MSW, characterized by variations in composition, density, moisture content, and size distribution.

The literature shows a need for research on the design and performance of MSW bag opener machines. Existing studies focus on other waste types or aspects of shredder machines, not on MSW bag opener machines. Research on blade design based on MSW characteristics will optimize the performance and durability of bag opener machines, improving subsequent sorting and separation processes. A new blade design is under theoretical investigation, with initial results from finite element analysis (FEA) to assess how different design parameters affect performance and durability. These results will guide the fabrication and integration of blade models into a prototype bag opener for further experimental investigations into blade performance and endurance.

3.0 METHODOLOGY

This research endeavors to enhance the bag-opening mechanism employed in waste treatment facilities globally, with a particular focus on the MENA region. Utilizing a mixed-methods approach, the study endeavors to devise and assess an innovative blade for the Municipal Solid Waste (MSW) bag opener machine, informed by the findings of an MSW study survey. The inquiry delineates and addresses four primary research queries pertaining to the characteristics and composition of MSW, the forces and stresses acting on the blades and ancillary components, the optimal materials and dimensions for both blades and associated components and the requisite operational power for the bag-opening mechanism.

The study is structured into four distinct phases to investigate these research questions systematically. Firstly, an MSW study survey is conducted to elucidate the characteristics and composition of Municipal Solid Waste. Subsequently, a blade design is formulated employing SOLIDWORKS. Following this, an evaluation of the blade's strength, performance, and durability is conducted utilizing static and fatigue Finite Element Analysis (FEA). Lastly, the operational power necessary for the bag-opening mechanism is computed through the application of force and torque equations. This methodological framework ensures a comprehensive examination of the bag-opening mechanism, contributing valuable insights to the field of waste treatment plant optimization.

3.1 Bag Opener (Pre-shredder) Blade Design Methodology

3.1.1 Design philosophy

The blade design of the MSW bag opener is important for achieving efficient and reliable operation. The blade design will be focused on in this paper, along with a general calculation for the MSW bag opener. The main factors that need to be considered for the design of the cutting blades and influence the blade design are the size, shape, material, speed, and power [31]. There is a direct relationship between the data collected from the MSW characterization study and the blade design development. In the following points, the effects of MSW characteristics on the blade design are presented.

- *The size of the blades* should be proportional to the size of the waste particles and the desired output size. Larger blades can handle larger waste particles, but they may also produce larger output sizes, which may not be suitable for further processing. Smaller blades can produce smaller output sizes, but they may also require more blades and more frequent replacement.

- *The shape of the blades* should be optimized for the waste composition and the shredding mechanism. Different blade shapes have different cutting angles, edges, and teeth, which affect cutting efficiency and output quality. For example, flat blades are suitable for soft and flexible materials, such as paper and plastic (e.g., MSW), while hooked blades are suitable for hard and rigid materials, such as wood and metal.
- *The material of the blades* should be selected based on the waste composition and the wear resistance. The blades should be made of durable and corrosion-resistant materials, such as steel, alloy, or carbide, to withstand the impact and friction of the waste. The material should also be compatible with the waste, as some materials may react with the waste and cause corrosion or contamination.
- *The speed of the blades* (i.e., drum speed) should be adjusted based on the waste composition and the power consumption. The speed of the blades determines the throughput and the output quality of the shredder. Higher speed can increase the throughput and the fineness of the output, but it can also increase the power consumption and the noise level. Lower speed can reduce power consumption and noise levels, but it can also reduce throughput and the coarseness of output.
- *The power of the blades* should be determined based on the waste composition and the energy efficiency. The power of the blades is related to the torque and the speed of the shredder. Higher power can enable the shredder to handle larger and harder waste particles, but it can also increase energy consumption and operating costs. Lower power can save energy and reduce the operating cost, but it can also limit the shredder's capacity and performance.

3.1.2 Assumptions for bag opener calculations

The quality and suitability of the pre-shredded waste for the subsequent treatment stages depend on the output lump size that preserves the recyclables. The processes of MSWT plants require a specific scale of this size, which is determined by the morphological and size characterization of the waste. The capacity of the MSWT plants also depends on several parameters, such as the bulk density of the waste and the efficiency and speed of the bag opener machine. Table 1 shows the main assumptions for the bag opener machine. The design of the bag opener drum and the arrangement of the blades are important factors that influence the performance and efficiency of the machine. The drum diameter is 800 mm [32], and the blades are arranged in a helical pattern, which maximizes the impact of each blade, prevents the material from wrapping around the drum, and ensures a uniform cutting pattern and high wear resistance [33]. The cutting chamber is the part of the machine where the blades break and separate the bagged waste from the plastic bags. The design of the cutting chamber aims to optimize the bag opening efficiency, the material throughput, the power consumption, and the noise level of the machine [34],[35]. The cutting chamber mainly consists of the drum with blade assembly and the fixed cutters (mesh or comb), which are positioned on two main sides to apply mesh sizing and enhance the opening process, as shown in Figure 1.

Table 1. Bag opener's main assumptions

Parameter	Values
MSW bag opened lump size (mm)	0-300, [33]
Mesh size [fixed cutters distances] (mm)	100, [36]
Drum diameter, D (mm)	800, [32]
Drum length, L (m)	2
No. of blades along the length, BL_L	17
No. of blades in diameter, BL_D	2
Total no. of blades, BL_T	34
Mean Radius Of acting force, R_m (mm)	650
No. of acting cutting edges, BL_A	3
Efficiency of bag opener, η	0.82, [35]
Drum rpm, N (rpm)	20, [34]

3.1.3 Blade geometry and size design

Due to the MSW characterization study results, four models of blades are designed and introduced for MSW bag opener, with different cutting-edge angles, as shown in Figure 2. All blades have the same cutting-edge dimensions of 180 mm in length and 20 mm in thickness. Due to the meshing requirements between the rotating blades and the fixed comb attached to the cutting chamber, a certain range for the cutting-edge angles of both the movable and fixed blades is needed to maintain high cutting performance. Model A has 60 degrees, Model B has 50 degrees, Model C has 45 degrees, and Model D has 30 degrees. All blades have two cutting direction options for efficiency and automatic cleaning. Based on the waste characterization results, the blade material was selected as DIN 1.0044 (S275JR) or ST-44, which is a wear-resistant material with mechanical properties shown in Table 2.

Table 2. Material DIN 1.0044 (S275JR) mechanical properties

Elastic Modulus (N/mm^2)	210000
Poisson's Ratio (N/A)	0.28
Shear Modulus (N/mm^2)	79000
Mass Density (kg/m^3)	7800
Tensile Strength (N/mm^2)	410
Yield Strength (N/mm^2)	275

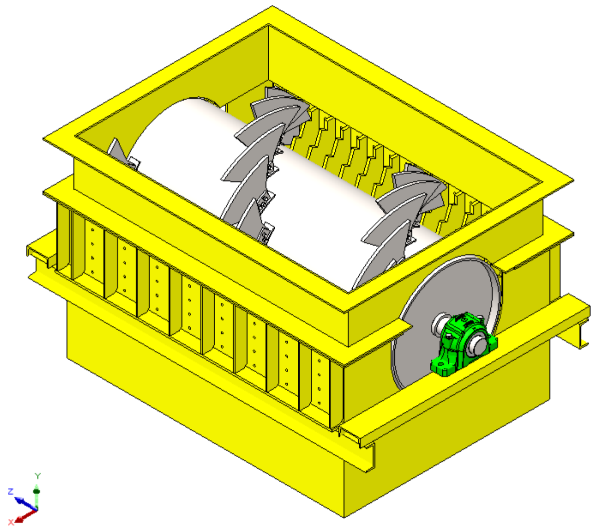


Figure 1. Drum design with blade arrangements assembled with the cutting chamber

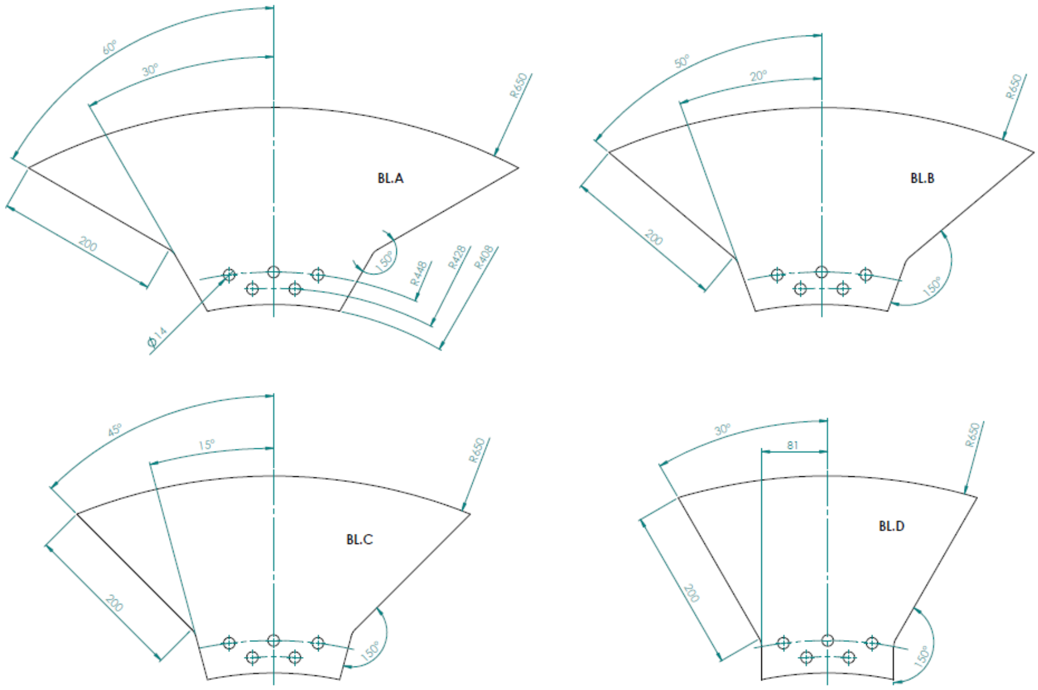


Figure 2. Different types of blade models

3.1.4 Bag opener capacity calculation

To calculate the capacity of the bag opener, follow the steps below:

a) Drum Surface Speed: (v) = π × Diameter × RPM
b) Throughput Calculation (T) = Surface Speed (v) × Drum Length × Efficiency
c) Volume Processed Per Minute: (V) = Throughput (T) × Blade Thickness
d) Mass Processed Per Hour (Q_m) = Volume Processed (V) × Density × 60 min/hr

3.1.5 Power Calculation

Although the shear strength for MSW is 250 kPa [37], 1 MPa is considered pressure acting on the cutting edge of the blade to compensate for any unexpected operating conditions, e.g., foreign materials' existence. To calculate the power consumption, the following steps can be followed:

a) The total Cutting Force (F) = No. of Active Blades (BLA) x Pressure (P) × Cutting Area (A) (N)
b) The Torque Required (T) = F × Radius (r)
c) Power Required (P) = (T × ω)/1000 (kW)
d) Motor Power selection (Pm) = P/efficiency (kW)

3.2 Finite Element Analysis

FEA is a numerical method for designing and optimizing bag opener blades, which are subjected to pressure and stress on their cutting faces during operation. To avoid failure and plan maintenance, the number of cycles that each blade can reach is calculated using static and fatigue FEA for each model using SOLIDWORKS software. Static FEA measures the von Mises stress (equation (1)), deformation, safety factor (equation (2)), and strain of the blades under load [38].

Fatigue FEA estimates the fatigue life based on the S-N curve of the blade material according to ASME carbon steel curves and a load factor of the blades based on repeating the static FEA results with zero-based (LR=0) [38].

$$\sigma_{\text{von Mises}} = \sqrt{\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + 3\tau_{xy}^2} \tag{1}$$

$$\text{FOS} = \frac{\sigma_{\text{yield}}}{\sigma_{\text{von Mises}}} > 1 \tag{2}$$

3.2.1 Mesh generation

A good mesh can capture the geometry and physics of the system accurately and reduce the errors and uncertainties in the solution. A blended curvature mesh type is applied, with Jacobian points set to 16 for high-quality mesh. The minimum number of elements in a circle is fixed at 8, and the element size growth ratio is set to 1.4 for all mesh size studies. The mesh study is applied to blade type A, which has the minimum material volume. Five sizes of mesh are applied to type A using mesh control, as shown in Table 3 and Figure 3.

Table 3. The dimensions of different mesh cases included in the mesh sensitivity study

Mesh Case		A-1	A-2	A-3	A-4	A-5	A-6
Mesh dimensions [mm]	Max. size	20	15	10	6	6	5
	Min. size	6	4.5	3	2.5	2	2.5
	Mesh control size	6	4.5	3	2.5	2	2.5

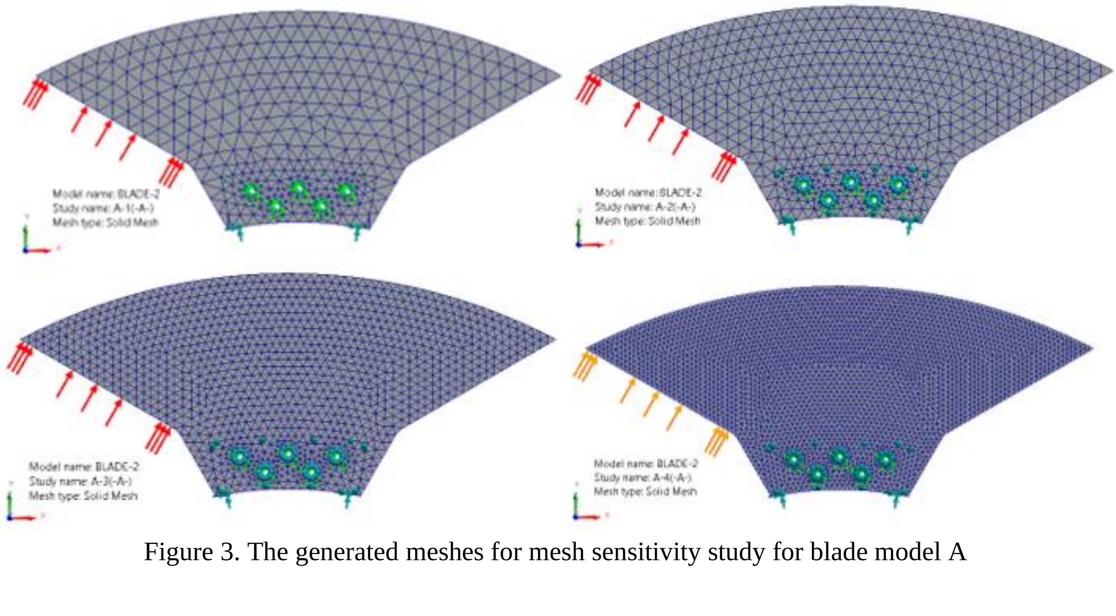


Figure 3. The generated meshes for mesh sensitivity study for blade model A

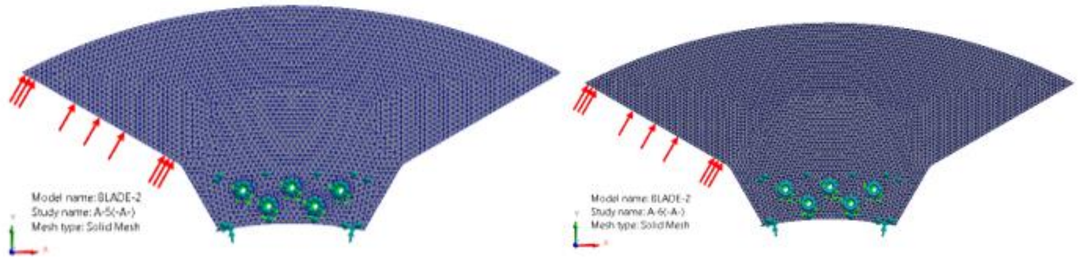


Figure 3. (cont.)

3.2.2 Mesh and boundary conditions

The required cutting pressure of 1 MPa is normally applied to the cutting faces. The system is assumed to be isotropic. For fixtures, all blades are fixed through five bolt holes (fixed faces), and the roller fixture is on supporting faces, as shown in Figure 4.

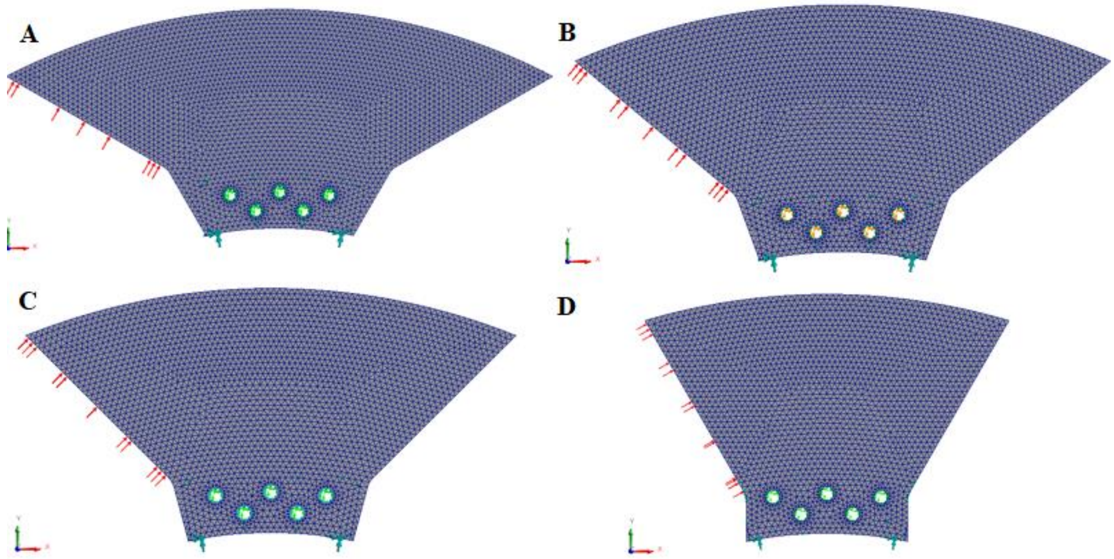


Figure 4. Mesh and Boundary conditions applied to each blade model

4.0 RESULTS AND DISCUSSION

4.1 MSW Study Survey Results

The main findings of a survey study from [22],[23],[24],[25] aimed to characterize the municipal solid waste (MSW) in the Middle East and North Africa (MENA) region. The study analyzed the waste composition in the MENA region and discovered that it had a high proportion of organic material, which constituted more than 50% of the total waste mass. The study also quantified the fractions of other waste components, such as cardboard, plastic films, recyclables, metals, glass, and others, as illustrated in Figure 5. The study estimated the average values of the MSW density and moisture content, which were within the interval of (250-450) kg/m^3 and 47%, respectively. Moreover, the study calculated the direct shear stress for MSW, which was 200 kPa. These results are utilized as input data for MSW bag opener design, such as pressure acting on the cutting blade, mesh size, blade material selection, and so on.

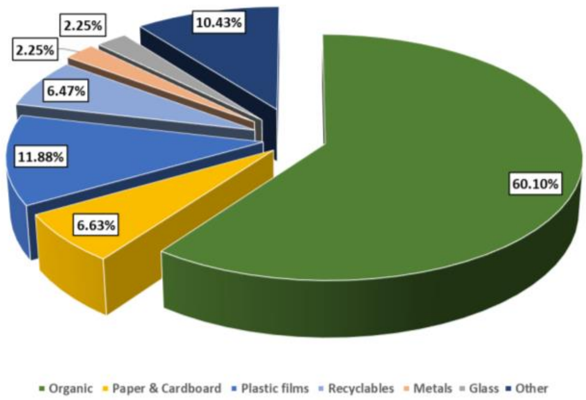


Figure 5. The AVG. waste characterization results in MENA region

4.2 Bag Opener (Pre-Shredder) Blade Design

4.2.1 Bag opener main calculation results

Capacity calculations: Table 4 illustrates the performance metrics of the MSW bag opener design, demonstrating its high capacity in waste processing. The Drum Surface Speed (v) is calculated at 50.27 m/Min., indicating the machine's fast operational speed. The Throughput Calculation (T) is estimated at 80.42 m²/Min., reflecting an impressive processing area per unit of time. The Volume Processed Per Minute (V) is valued at 1.61 m³/Min., signifying a substantial volume of waste handled effectively. The Mass Processed Per Hour (Q_m), computed at 29.68 tons/hrs., reveals the machine's ability to manage a significant mass of waste expeditiously.

Table 4. Capacity calculations

Parameter	Values
Drum Surface Speed, ν (m/Min)	50.27
Throughput Calculation, T (m^2/Min.)	80.42
Volume Processed Per Minute, V (m^3/Min.)	1.65
Mass Processed Per Hour, Q_M (ton/hr.)	29.68

Power calculations: Table 5 presents various parameters that evaluate the power demand and utilization of the MSW bag opener design. The table reveals that the MSW bag opener design necessitates a substantial amount of power to function effectively. For instance, it demands approximately 16 kW of power to spin the drum and rip the bags. The motor efficiency is recorded at 0.8, which implies that 80% of the electrical energy is transformed into mechanical energy. The motor power estimation is around 20.42 kW, which indicates that the motor has to provide more power than the MSW bag opener actually requires. The standard power selection is 22 kW, which is the nearest standard value to the motor power estimation.

Table 5. Power calculations

Parameter	Values
Cutting force acting on one blade, F_B (N)	4000
Total cutting force, F_T (N)	12000
Required Torque, T (N.m)	7800
Power required, P (kW)	16.34
Motor efficiency, η_m (-)	0.8
Motor power Estimation, PW (kW)	20.42
Standard Power Selection, P_{motor} (kW)	22

4.2.2 Mesh sensitivity analysis

The impact of mesh refinement and local control on the stress, strain, and FOS is demonstrated in Figure 6. The figure portrays the examination of distinct mesh cases denoted as A-1 to A-6, aimed at discerning variations in the aforementioned parameters. The left-hand graph elucidates a discernible trend wherein maximum stress exhibits an incremental rise, concomitant with a decrement in FOS (yield strength/max. stress) across successive mesh cases. Likewise, the right-hand graph delineates the extremities of strain values across diverse mesh cases, revealing discernible alterations in both maximum and minimum strain.

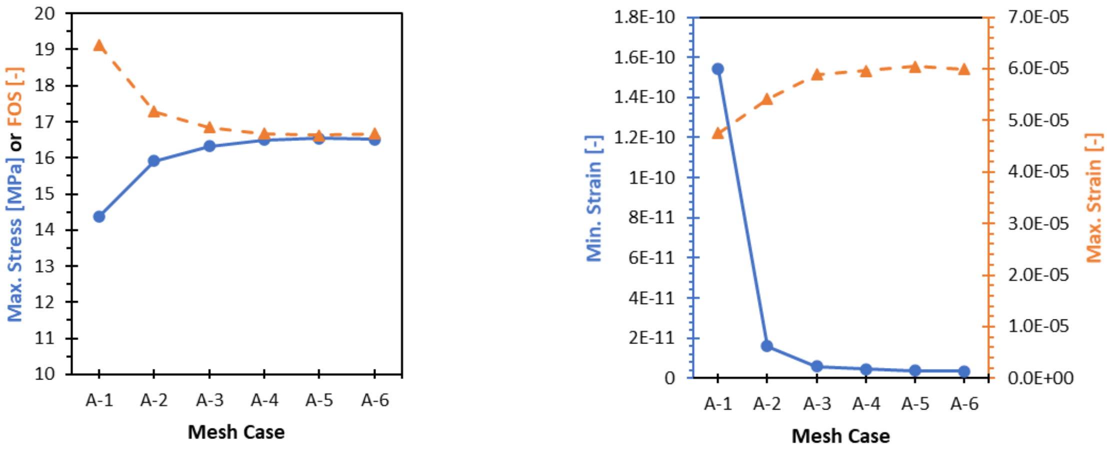


Figure 6. The effect of mesh refinement and control on the maximum stress and FOS (left) and the minimum and maximum strain (right)

It is noteworthy that all parameters converge towards a state of stability at the refinement level of case A-3. This phenomenon can be ascribed to the heightened precision in capturing intricate geometrical features and stress concentrators as the mesh undergoes refinement. This observation posits that finer meshes provide more accurate insights into potential vulnerabilities or regions characterized by elevated stress concentrations. In essence, the findings underscore the pivotal role of mesh refinement in enhancing the accuracy of FEA results, particularly in the identification of critical stress points and areas susceptible to structural weaknesses.

4.2.3 Static FEA assessment

This section presents and discusses the static FEA results obtained using SOLIDWORKS software. Figure 7 shows the stress distributions of the four models of blades under pressure. Stress and strain are measures of the internal force and deformation of the blades. The lower the stress and strain, the better the blade can resist the pressure and maintain its shape. As shown in Figure 8, model D has the lowest values of maximum stress (15.18 MPa) and maximum strain (5.5 x10^{-5}), while model A has the highest values of maximum stress (16.5 MPa) and maximum strain (6x10^{-5}). Models B and C have semi-similar values of maximum stress (16.01 MPa and 15.68 MPa, respectively) and maximum strain (5.7 and 5.6x10^{-5} respectively). The maximum stress and strain distribution for all models is concentrated in the nearest hole to the cutting edge of each blade.

Figure 9 shows the FOS and displacement distributions of the four models of blades under pressure. The FOS is a measure of the safety margin of the blades, which indicates how much the stress can increase before the blade fails. The higher the FOS, the safer the blade is. The displacement is a measure of the movement of the blades, which indicates how much the blade changes its position under pressure. The lower the displacement, the more stable the blade is. As shown in Figure 9, model D has the highest value of minimum FOS (18.12) and the lowest value of maximum displacement (8.7x10^{-3} mm), while model A has the lowest value of minimum FOS (16.67) and the 17.17and 17.54, respectively) and maximum displacement (1.4 and 1.2 mm x10-2 respectively), the Min. FOS values for all blade models are located in the same area of the maximum stress and strain values, although the maximum displacement distribution for all blade models are distributed around the blade cutting edge.

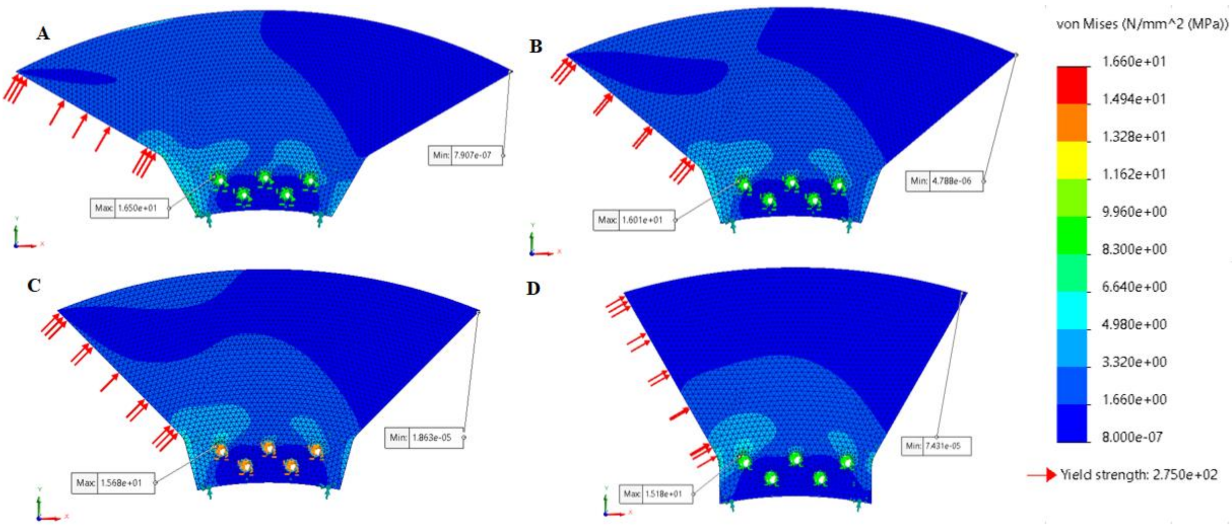
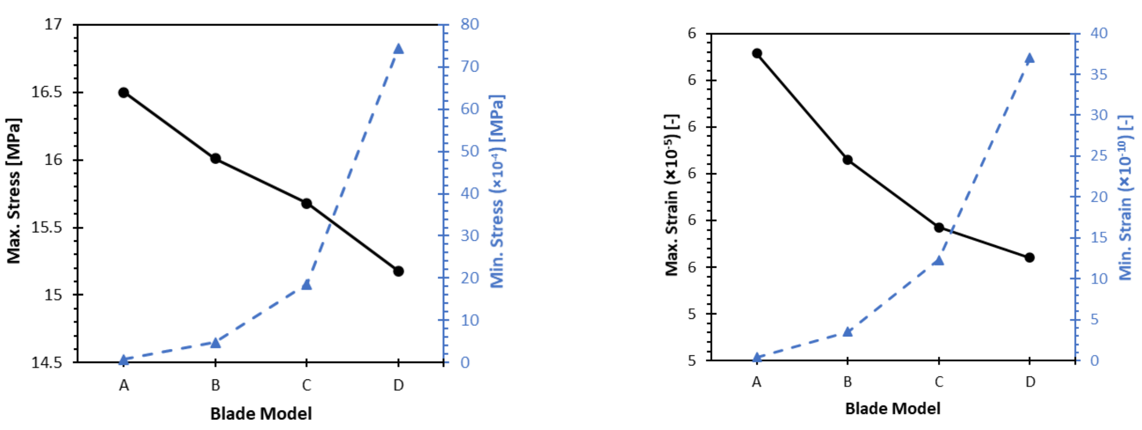


Figure 7. The Von Mises stress analysis



(a) Stress (von Mises) (b) Strain

Figure 8. The maximum and minimum stress and strain of each blade model

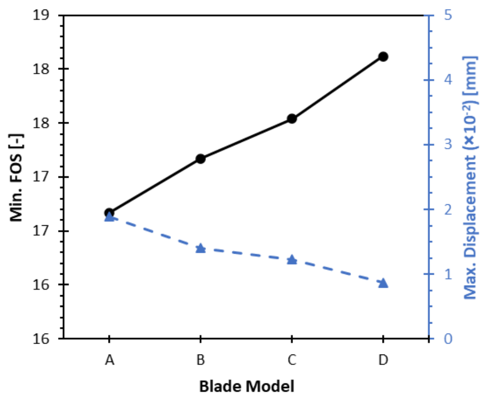


Figure 9. The minimum FOS and maximum displacement of each blade model

4.2.4 Fatigue assessment

This section presents and discusses the fatigue FEA results for the four models of blades under repeated pressure. The fatigue FEA is a method that analyzes the fatigue load factor and the fatigue life of the blades. The fatigue FEA helps to evaluate the performance and durability of the blades and to compare and select the optimal blade type for the MSW bag opener machine.

Figure 10 shows the fatigue load factor distributions of the four models of blades under repeated pressure. The fatigue load factor is a measure of the safety margin of the blades, which indicates how much the stress can increase before the blade fails. The higher the fatigue load factor, the safer the blade is. As shown in Figure 10, model D has the highest value of minimum fatigue load factor (9.99), while model A has the lowest value of minimum fatigue load factor (9.18). Models B and C have values of minimum fatigue load factor (9.46 and 9.67, respectively).

All blade models have the same value of minimum fatigue life (10^6 cycles), which means that they can survive at least 10^6 cycles of rep-9eated pressure. The reason is that the maximum stress for each blade is lower than the fatigue endurance limit, which is the stress level below which the blades can endure an infinite number of cycles without failing. However, this does not mean that all blade models have the same strength, performance, and durability, as the fatigue load factor results show that model D has a higher safety margin than the other types.

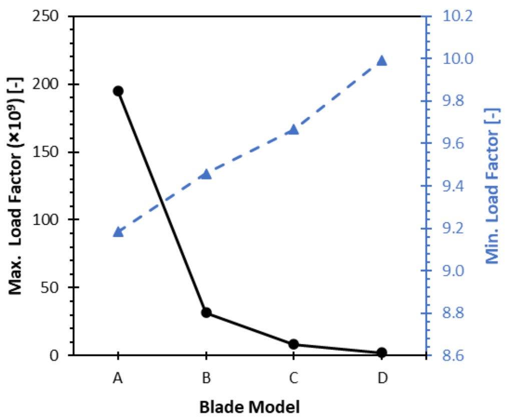


Figure 10. The minimum and maximum load factor of each blade model

Based on the static and fatigue FEA results, the paper selects model D as the optimal blade model for the MSW bag opener machine, as it has the lowest stress and strain, the highest FOS from static analysis and the highest fatigue load factor and the same fatigue life as the other models from fatigue analysis. The results also note that model A is the worst blade model for the MSW bag opener machine, as it has the highest stress and strain, the lowest FOS, the lowest fatigue load factor, and the same fatigue life as the other types. Models B and C are intermediate blade models that have similar strength, performance, and durability, but they are inferior to model D. The paper also relates the fatigue FEA results to the blade design and geometry, the blade material and coating, and the operational power and efficiency of the bag opener machine, and discusses the implications and limitations of the results.

5.0 CONCLUSIONS

This paper addressed the design and optimization of blades for MSW bag opener machines, which is crucial for efficient waste management. The research question focused on finding the optimal cutting edge angle for the blade. This paper presented a novel and comprehensive methodology for designing and evaluating optimal blades for MSW bag opener machines. The results confirmed existing blade design theories and contributed to the field of MSW bag opener machines. The findings suggest that improving blade design can enhance the efficiency, effectiveness, and sustainability of waste management. FEA results showed that Von Mises maximum stress and minimum factor-of-safety (FOS) for the four blade models (A, B, C, and D) are 16.5, 16.01, 15.68, and 15.18 MPa, and 16.67, 17.17, 17.54, and 18.12, respectively. Model D, with a 30° cutting edge angle was selected as the best blade model, with the lowest Von Mises stress (15.18 MPa) and highest FOS (18.12), indicating a long service life of 10^6 cycles. This research contributed valuable insights and recommendations for improving the design and operation of MSW bag opener machines and the overall waste management process.

Recommendations for future research include investigating different blade shapes, sizes, and materials, optimizing blade coating and lubrication, and comparing various types of MSW bag opener machines. Proposed methods for future studies include experimental testing, multi-objective optimization, and life cycle assessment.

6.0 ACKNOWLEDGEMENT

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7.0 ABBREVIATIONS

ADEME	Agence de l'Environnement et de la Maîtrise de l'Énergie (Agency for the Environment and Energy Management).
DIN	Deutsches Institut für Normung (German Institute for standardization).
FEA	Finite element analysis.
FOS	Factor-of-safety.
MBT	Mechanical/biological treatment.
MENA	Middle East and North Africa.
MODECOM	Méthode d'Observation et de Description des Éléments et Comportements des Ordures Ménagères (Method of Observation and Description of Household Waste Elements and Behaviors).
MSW	Municipal solid waste.
RVM	Reverse vending machine.

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