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Finite Element Analysis of Rope Machine From Waste Plastic Bottles

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Abstract- Plastic contamination is a terrible issue nowadays. The oceans are flooded with plastic waste, which even causes it's entering into our food chain. Such bottles are constructed from high density plastics that are typically, Bottles used to store liquids such as water, soft drinks, motor oil, cooking oil, medicine, shampoo, milk, and ink. They are non-biodegradable and the improper disposal of such products will definitely have a huge impact on our environment. Advances in technologies and systems for the collection, sorting and reprocessing of non-recyclable plastics are creating new opportunities for converting such bottles into useful products. This work is an attempt to figure out a solution to the disposal of plastic bottles that are usually dumbed into open environment. Bottles that commonly arrive at disposal sites are Poly Ethylene Terephthalate (PET). In this work, PET bottles are cut into strips, twisted and heated into a rope using an automated machine which consist of a cutting unit, temporary plastic strip storage unit and a strip joining unit. The rope thus produced is tested for strength and is found to be suitable for several applications. The work thus aids not only in solving the ill effects caused by disposed plastic bottles but also helps our society move towards sustainability.

Plastic bottles are increasingly becoming a menace to the environment due to the chemicals used in the manufacture, improper and disposal. Instead of going for traditional method of recycling the plastic in the environment which is not very economical we can easily reuse plastic by converting waste bottles into useful things which come handy.

The use of numerical simulations has been wide spread in many engineering fields and related areas. One of the main numerical methods used in modeling and simulations is the finite element method (FEM). As result, it is expected greater FEM dissemination in rope making machine for analysis can be used in simulate how entire structure or system behaves and used in order to represent the increasing behavior of rope making machinery.

Keywords:-FEM, analysis, plastic bottles, disposal, environment, PET bottles, rope.

1.INTRODUCTION

Finite Element Analysis (FEA) was developed in 1943 by R. Courant, who used the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions for systems of vibration. Shortly after, an article published in 1956 by MJ Turner, RW Clough, HC Martin, and LJ Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deformation of complex structures”. FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in the design of new products, and refinement of the existing product. A company is able to verify a proposed design and will be able to perform the product specification of the client before fabrication or construction. Modifying an existing product or structure is used to qualify the product or structure of a new condition of service. In the caseof structural failure, FEA may be used to help determine the design modifications to meet thenew condition.

There are generally two types of analysis that are used in the industry: 2-D modeling, and3-D modeling. While 2-D modeling conserves simplicity and allows the analysis to beperformed on a relatively normal computer, it tends to give less accurate results. 3-Dmodeling, however, it produces more accurateresults sacrificing the ability to run on allcomputers faster, but actually [6]. Development of the finite element method (FEM) in the early 1970s pioneered the firstsimulations of orthogonal machining process. First research work used as a self-developmentof finite element code. Since 1990 starts massive use of commercial software, which is ableto model the process, as NIKE2, ABAQUS / Standard, MARC, ABAQUS / Explicit, deform2D FLUENT, FORGE 2D, ALGOR, LS DYNA [7]. Finite Element Method (FEM) modeling and simulation of manufacturing processes based iscontinually attracting researchers to a better understanding of the mechanisms of chipformation, heat generation in the areas of cutting, tool-chip interface friction characteristicsand integrity on the machined surfaces. Forecasts of the physical parameters such astemperature and stress distributions play a key role with precision machining processespredictive process engineering. Tool edge geometry is particularly important because it isinfluence on tool life to achieve geometry is particularly important because it isinfluence on tool life to achieve more desirable surface integrity is extremely high [8]. Therefore, the development of FEM models based on continuous, accurate and soundcharacteristic are needed in order to study the influence of the cutting edge geometry, mechanisms of tool wear and cutting conditions on the surface integrity and residual stresseson the machined surfaces. This paper aims to predict cutting forces, temperatures and residualstresses on the machined surface. FEM has some advantages, as it solves problems of contact, bodies of different materials areused, curvilinear region can be approximated by finite elements or described accurately, etc. There are two types of formulations finite elements to describe a continuous medium: Lagrangian and Eulerian.

The Lagrangian is widely used. In an analysis of Lagrange, grid mesh deforms with thematerial, while in the Eulerian analysis grid is fixed in space. The Lagrangian analysissimulates the entry, exit, stages of intermittent and discontinuous chip formation, while theEulerian cannot simulate the phases of intermittent and discontinuous chip formation. However, the Eulerian formulation eliminates the need for a chip criteria of division and toavoid distortions of the mesh [9]. In this project work modelling and analysis is done using ANSYS and DEFORM-2D. The Finite Element Method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. In simple terms, FEM is a method for dividing up a very complicated problem into small elements that can be solved in relation to each other. Useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained. Finite Element Analysis (FEA) was developed in 1943 by R. Courant, who used the Ritz method of numerical analysis and minimization of variational calculus to obtain approximate solutions for systems of vibration. Shortly after, an article published in 1956 by MJ Turner, RW Clough, HC Martin, and LJ Topp established a broader definition of numerical analysis. The paper centered on the "stiffness and deformation of complex structures”.

1.1 Literature Review-

The first totally man made made polymer to be synthesized was the phenol Formaldehyde resin(called Bakelite at the time) made by Leo Backeland in his garage in Yorkers,New York, back in 1907. It was an immediate success not only as Replacement for shellac in electrical wiring (the primary reason for its invention) but also in numerous consumer uses including the body of the old black dial telephones and in early electrical fittings. Since that time, plastics have grown rapidly and have now become an indepensable part of everyday life. The exponential growth of plastics and rubber use, essentialy over a short period of half a century, is a testimony to the versatility, and cost effectiveness of polymers as a class of materials

Polymer derive their exceptional properties from an unusual molecular architecture that is unique to polymeric material,consisting of long chain like macromolecules. While both plastics as wellas elastomers (rubber like materials) are included in polymers, discussions on environment-related issues have mostly centered around plastics because of their high visibility in packaging and building applications. Many of the common thermoplastics used today, however, were developed after the 1930s; and few of these even emerged after World War two.Among the first to be synthesized were the vinyl plastic derived from ethylene. But the now common rigid PVC used in building was apost war development that rapidly grew in volume to a point that by the early 1970s the demand for vinyl resin was closed to that for polyethylene! Polyethylene, the plastic used in highest volume worldwide, was discovered at Imperial Chemical Industries (ICI) research laborarities in 1933. This high pressure polymerization rout was exclusively used to commercially produce low-density polyethylene (LDPE) for nearly tow decades until the low pressure processes for high high -density polyethylene (HDPE) WERE DEVELOPED IN 1954. Linear low-density copolymers of ethylene (LLDP), intermediate in structure and properties between the HDPE and LDPE, followed even more recently in the 1970s. In the last decade yet another new class of polyethylene based on novel metallocene catalysts has been developed. Polyethelene manufracture started relatively late in the 1950s only after the stereospecific Ziegler-Natta catalysts that yielded high molecular-weight propylene polymers became available. While a range of copolymers of ethylene is also commercially available, the homopolymer of propylene enjoys the highest volume of use.

Polyethylene, polypropylene (and their common copolymers) are together referred to as polyolefin. Several other common thermoplastics emerged about the same time as LDPE in 1930s. Polystyrene, for instance, was first produced in 1930 and by 1934 plants were in operation producing the commercial resin in both Germany and the United States. Poly (methyl methacrylate) (PMMA) was developed by ICI about the same period . Carothers discovery of nylons (introduced in 1939 at the World’s fair in new York) yielded a material that particularly served the allied war effort.

In regions of the world where natural gas is not readily available., petroliam or coal tar is in fact used exclusively as feedstock. About the polyolefins produced in United State stoday is based on petroliam, the remainder being derived from natural gas. The crude oil is distilled to separate out the lighter componants such as gases, gasoline, and kerosene fraction. Cracking is the process of catalytically converting the heavier componants (or “residues” from the distillation) of crude oil into lighter more useful componants.About 45% of the crude oil reaching a refinery is converted to gasoline.

Leterature revieves with FEM :

Modeling Polymer Behavior and Mechanical Properties: Researchers have developed constrictive model to describe the creep and relaxation behavor of polymers.T hese model help predict how PET bottles respond to different loads and environmental conditions.

Preform Optimization: Preforms are initial shapes before blow molding. Optimizing preform design ensures better final bottle quality.

Blow Molding:Understanding the blow molding process is crucial for PET bottle production. FEM simulation aid in optimizing the blow moulding parameters.

Structural Performance: Researchers have investigated the structural integrity of PET bottles under varios loading conditions.

1.2 Gaps and opportunities

Gaps:

Current cutter designs, however, have limited functionality in the size of bottle and srip width the are able to accommodate and must be improved.

The contraption is bulky and requires a table or a vice to secure it in place or the sring gets jammed some where during cutting and break.

- Lack of experience.
- Lack of capital funding.
- Lack of government and customer support base.
- Incoming material needs to be of certain quality to be useable.
- Lack of reliable electricity supply in village.
- Lack of reputation

2.METHODOLOGY

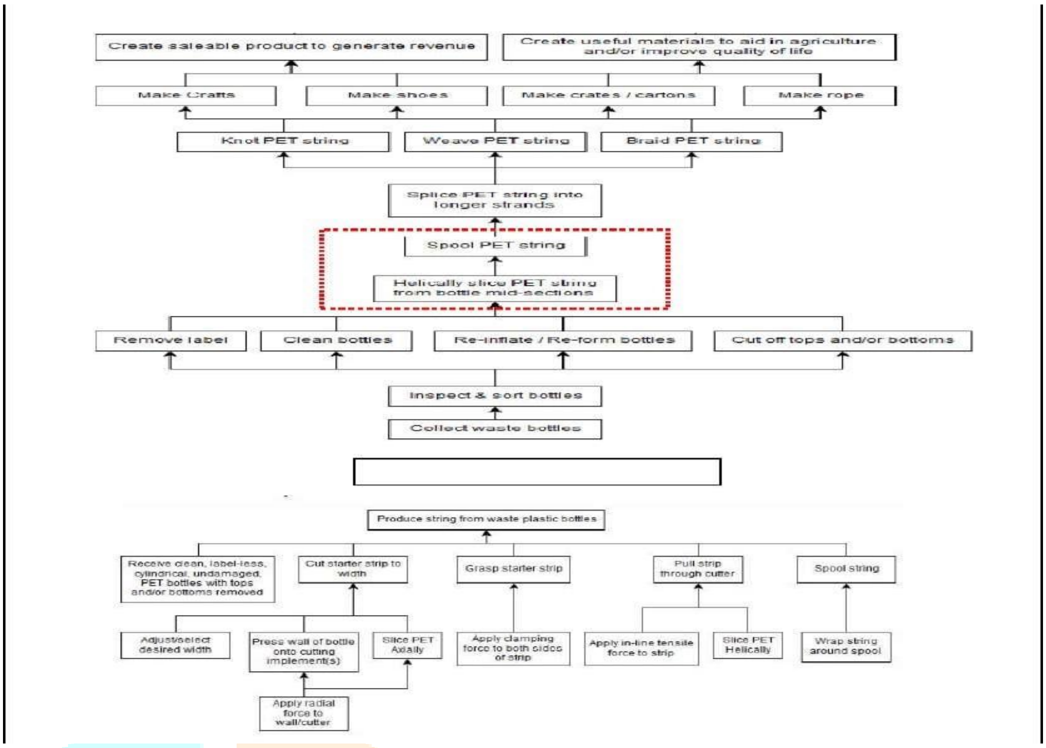


Fig 1. Chart of methods used in rope making machine from waste plastic bottles

2.1 Potential Concepts:

Benchmarking found that concept of cutting PET bottle into string has existed for quite some time. Methods range from something as a simple a razorblade bolted between stacked washers, clamped to a commertially available, hand held, adjustable device.

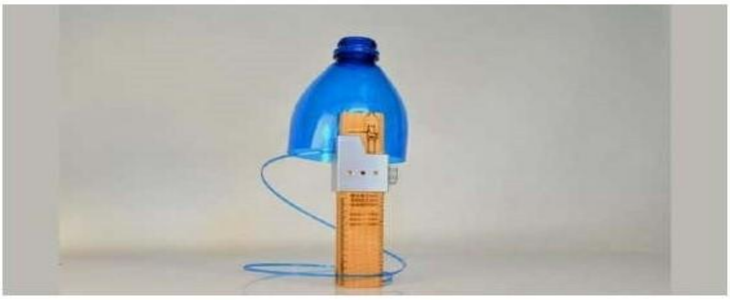


Fig 2. Cuttur diagram

The existing methods rely on manually pulling the material through the cutter. Depending on the force and angle at which it is pulled, as well as the quality of the cutting edge, the resulting string can be of a varying, inconsistent width. After making the string, it needs to be manually looped or wrapped as pool.

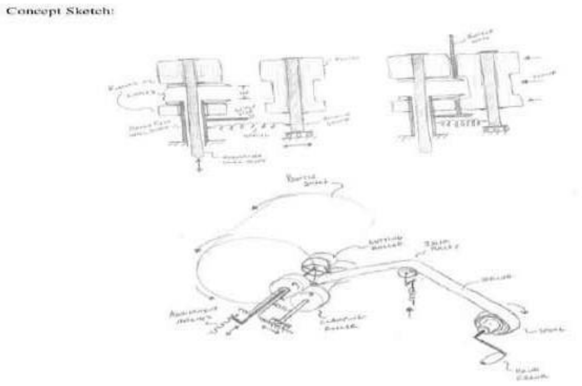


Fig 3. Concept sketch

3.OBJECTIVE

This finite element analysis of rope making machine aims to not only increase the value of the bbottles by using them for something constructive , but to also economy with their worth. By first turning waste bottles into durable PET string, it can be reporposed for a veriety of useful and potentially profitable application. By doing this we can reduce the wastage of plastic bottles and thereby reuse them and thus reducing the pollutants in the invironment. We have worked to design and prototype PET Bottle Strip Cutter.

3.1Consruction and working principle of machine:-

Working principle: The working principle of the plastic rope making machine is to arrange several yarns with a certain linear density according to the technological requirements and twist them into strands in the opposite twisting direction. There are two common types of rope making machines: during the operation of the machine, the stock cake not only rotates around its own axis, but also runs along with the main shaft of the machine, which is called a spinning stock machine; The axis of its own axis rotates and reciprocates, and the spindle of the machine does not rotate, which is called a constant ingot strand making machine. The application of the rope making machine greatly improves the production efficiency, reduces the working procedures from strand to rope making, no waste filament or waste is generated, and the rope made is more beautiful and durable.

Consruction: The construction of single motar is in the armature with 8 slots is mounted on self lubrication sintered bushes. Two carbon brushes, set 180 degrees apart, rub on an 8 segment commutator generally installed at the driving end. Two strong permanent magnet are bonded to the steel yoke using adhesive, which is sometimes coated externally with non ferrous metal to protect it against corrosion. A steel warm, formed on the end of armature, drives a plastic worm wheel at speed of about 1/10th the speed of armature. The motar has the output drive through a pinion gears, driven directly by the warm wheel. At the joint faces of the motar, rubber seals are fitted to protect it from moisture. The wiper motars now in use are mostly of permanent magnet three brush types, which are driven through a warm gear to increase torque and reduce speed. The three brushes permit two speed operations. The normal speed is achieved through two brushes placed in the usual position opposite to each other. For a fast speed the third brush is installed closer to the earth brush. This design reduce the number of armature winding between them, which reduce resistance and consequently increases current and hence speed.

Fig 4. Rope making machine

3.2 FORMULATION OF RESEARCH PROBLEM

Problem formulation of finite element analysis of rope making machine from waste plastic bottles involves several steps;

Problem Formulation: -

1)Define the Objective: Start by clearly defining the objective. In this case, it could be improving the cutting performance, reducing wear and tear, enhancing safety, or any other specific goal.

2) Identify Key Components: Identify the key components of the cutting machine that are critical to its performance, such asblades, gears, motors, and structural elements.

3) Material Properties: Collect material properties data for the components. This includes information on the tensile strength, modulus of elasticity, density of the materials used.

4) Load and Boundary Conditions: Determine the loads and boundary conditions the machine experiences during operation. From rope making machine, this may include the forces exerted by the cutting process, vibrations, and external loads during transportation.

5) Geometry and CAD Modeling: Create a detailed CAD model of the cutting machine and its components. This model shouldaccurately represent the machine's geometry.

6) Mesh Generation: Generate a finite element mesh for the model. The mesh divides the geometry into smaller elements, whichare necessary for FEA calculations.

7) Define Analysis Type: Choose the type of FEA analysis to perform. This could be static analysis, depending on the specificproblem you are addressing.

8) Material Assignment: Assign material properties to the elements in the mesh based on the components' materials.

9) Apply Loads and Constraints: Apply the loads and boundary condition identified to FEA model.

10) Solve the Model: Use FEA software to solve the model and obtain results. These results may include stress distributions, deformation patterns, and other relevant data.

11) Evaluate Results: Analyze the results to determine if the machine meets the desired performance criteria or if any areas ofconcern are identified. 12)Documentation: Document the entire FEA process, including assumptions, inputs, and results, for future reference andpotential regulatory compliance. potential regulatory compliance. By following these steps, you can effectively identify and formulate FEA for a rope making machine, helping to improve its performance, durability, and safety. Basic steps & Phases Involved in FEA:

STEPS: -

- Discretization
- Selection of approximation of functions
- Formation of elemental stiffness matrix
- Formation of total stiffness matrix
- Formation of element loading matrix
- Formation of total loading matrix
- Implementation of boundary condition
- Calculation of unknown nodal displacements
- Formation of overall equilibrium equation
- Calculation of stresses and strains

PHASES

Pre-Processing: Here a finite element mesh is developed to divide the given geometry into subdomains for mathematical analysisand the material properties are applied and the boundary Conditions. Solution: In this phase governing matrix equation are derived and the solution for the primary quantities is generated. Solution: In this phase governing matrix equation are derived and the solution for the primary quantities is generated. Post-Processing: In the last phase, checking of the validity of the solution generated, examinations of the values of primary quantities such as a displacements and stresses, errors involved is carried out.

4. MODELING & ANALYSIS -

The 3d isometric view of rope making machine from waste plastic bottles, including different operation by solid works CAD software.

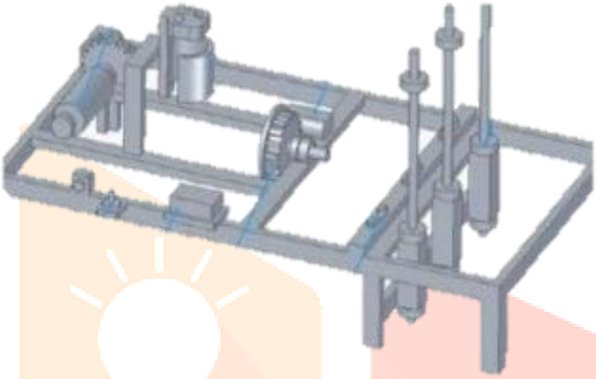


Fig.5- 3-D view of rope making machine

Analysis:

A. Mesh of model

FIGURE 2
Model (A4) > Mesh > Figure

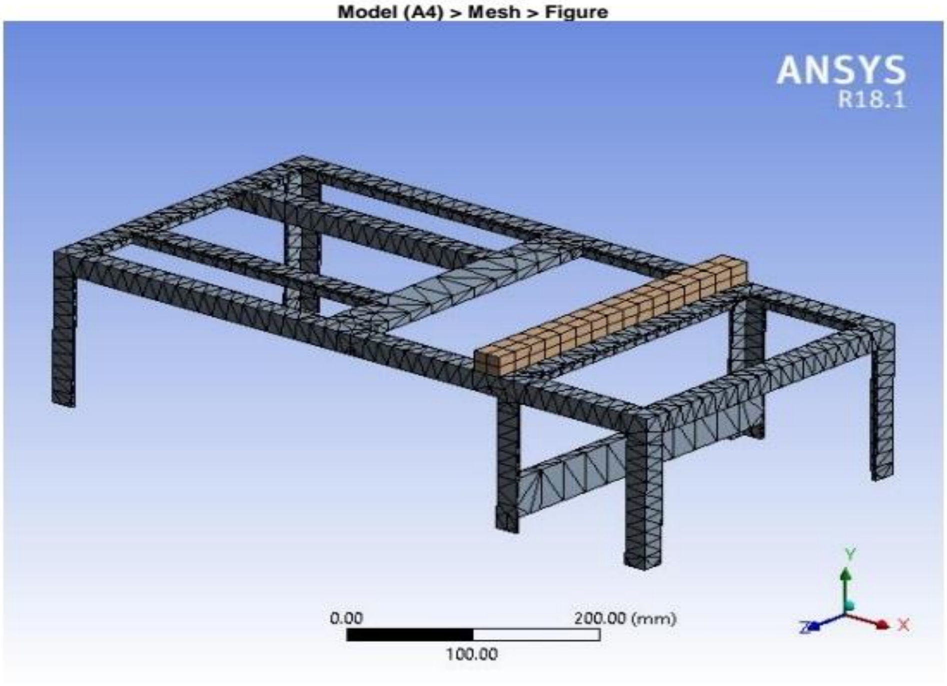
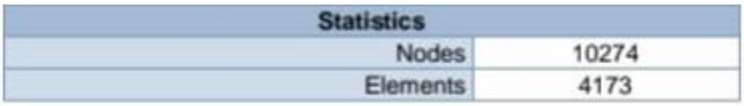


Fig.6- model (A4) mesh

Table 1. nodes of elements of model



Statistics	
Nodes	10274
Elements	4173

B. Total deformation of model:

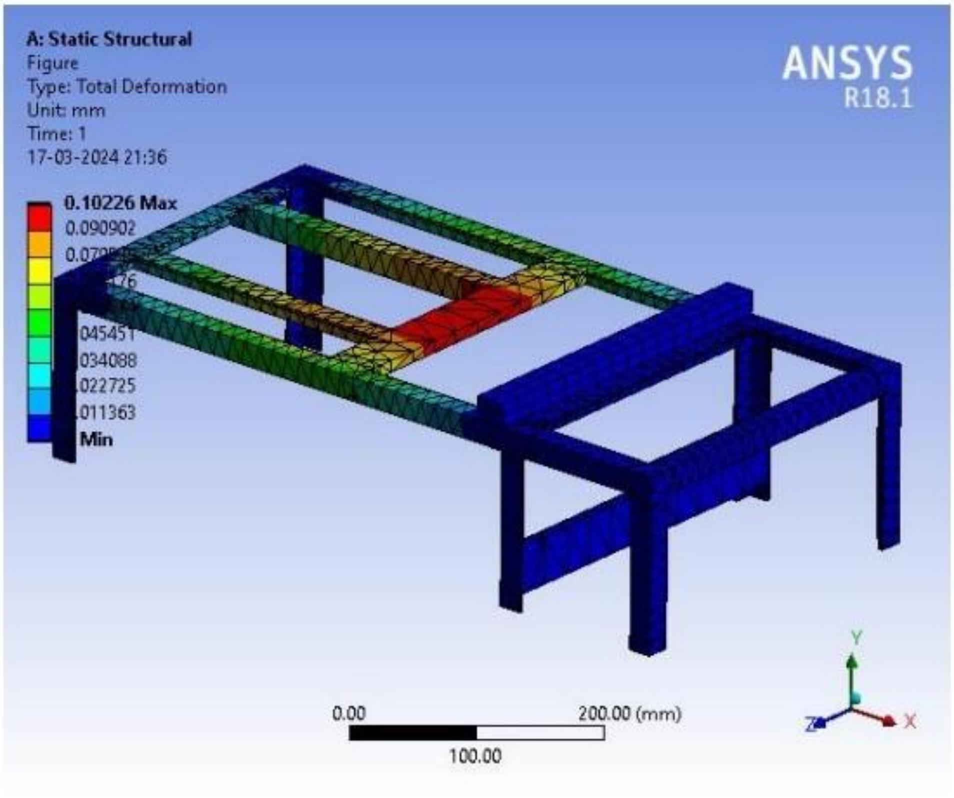


Fig.7- Total deformation of model

Table 2. Deformation of model

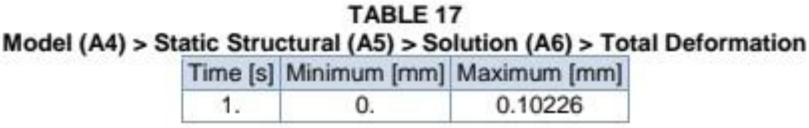


TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]
1.	0.	0.10226

C. Equivalent stress of model

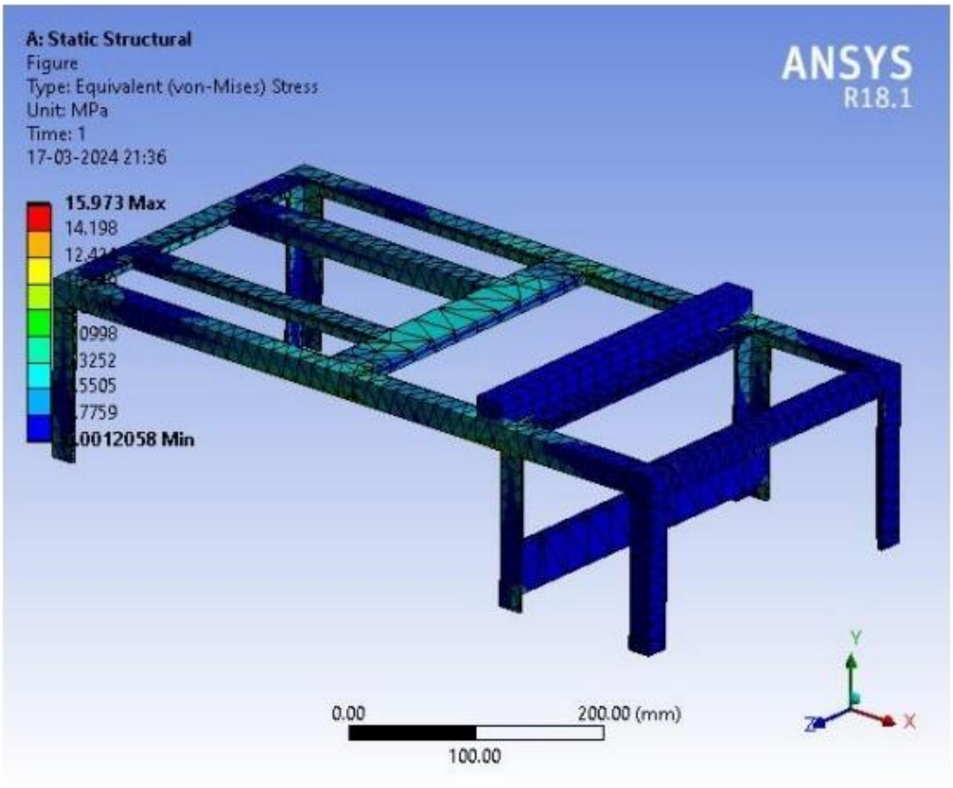


Fig 8. Equivalent stress of model

Table 3. Stress of model

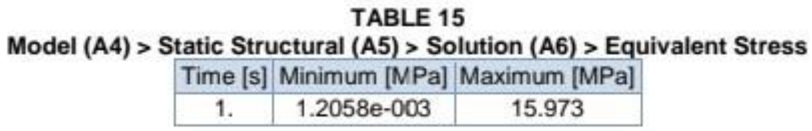


TABLE 15
Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Stress

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	1.2058e-003	15.973

D. Equivalent elastic strain of model

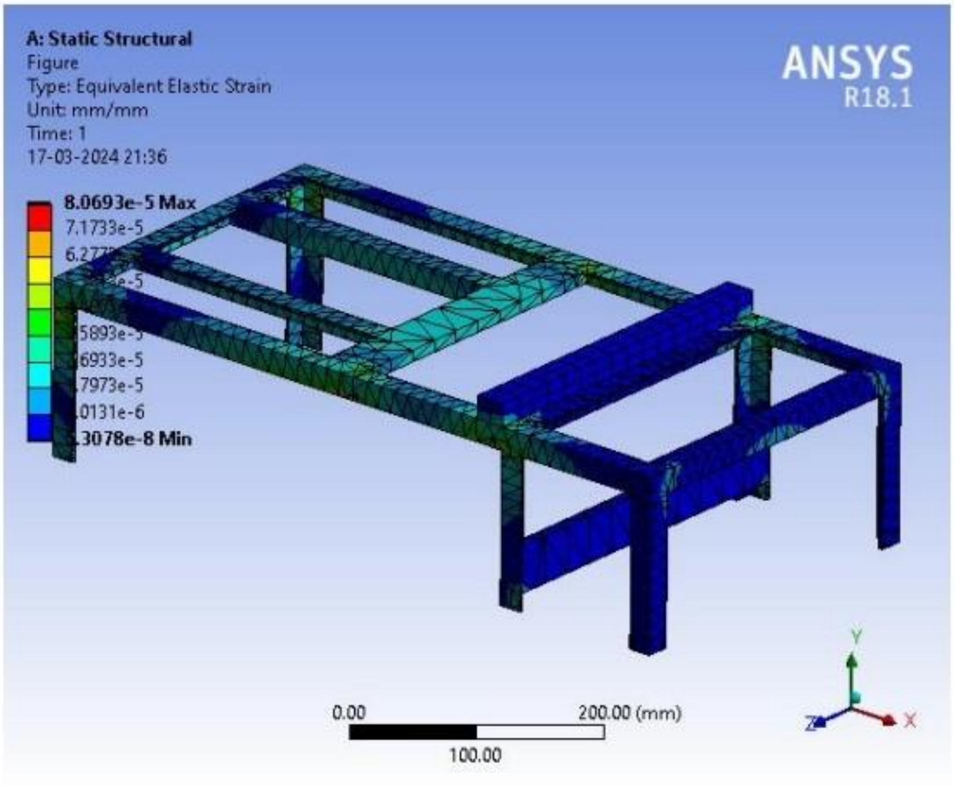


Fig 9. Equivalent elastic strain of model

Table 4. Elastic strain of model

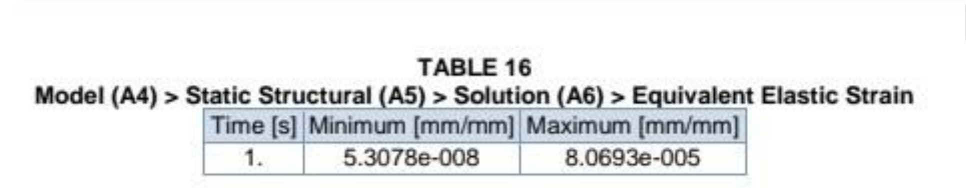


TABLE 16

Model (A4) > Static Structural (A5) > Solution (A6) > Equivalent Elastic Strain

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	5.3078e-008	8.0693e-005

5. RESULT AND DISCUSSION -

1) Finite Element Simulation of Various Components: Developed three-dimensional model of implement was uploaded in ANSYS R18.1 software for doing static structural analysis on various components. Standard material properties like Young’s Modulus, ultimate tensile strength, yield strength, Poissons’s Ratio, density, etc. were provided to the software for further stress analysis. Proper connections between different components were established. Meshing method and size were selected to create mesh structure of different components. Theoretical calculations were done for various components taking shock and fatigue factors into consideration, and resulting values were used to apply force, moment and boundary constraints on the designed 3D model. The results of induced Von Mises stress and total deformation were analyzed, and necessary design changes were done accordingly in the 3D model to achieve optimum part dimensions for product development. Results of FE analysis are presented here in the form of coloured contours representing stress levels and deformation variation on the model.

2) Finite element analysis of the main frame: Applied forces and boundary conditions for FE analysis of the main frame are shown in Fig. 6. The results of finite element analysis are shown in Figs.7,8 and 9. The total deformation(0.10226mm) of the model should have maximum equivalent stress induced (15.973MPa). The maximum equivalent Elastic Strain of Model has 8.0693e-005mm/mm.

6. CONCLUSION -

Based on the results obtained in this study, the following specific conclusions can be drawn:

1) The three-dimensional model of Rope making machine from waste plastic bottles was successfully created in SolidWorks 2021, and optimum part dimensions were achieved by doing FE analysis in ANSYS R18.1 workbench software. The simulation was very helpful to understand the effect of different forces on the model.

2) The stress induced and the deformation of each component were found to be less than the allowable stress and maximum deformation of the material selected which signifies the safe design of implement.

3) FEM enables to optimize and simulate the complex agricultural machinery and to investigate the stresses, deformations and safety factor induced in the parts well before product development to avoid failure in the later phase of field evaluation .

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