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FINITE ELEMENT ANALYSIS OF FRP-STEEL COMOPSITE CHAFF CUTTER BLADES WITH DIFFERENT BLADE BEVEL ANGLES

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Abstract
In order to address the demand for lightweight and durable materials in those particular industries, the use of composite materials is expanding quickly across a variety of industries. For instance, the U.S. market for only glass fiber reached 2.5 billion pounds in volume and $ 2.1 billion in value in 2017. The aerospace, automotive, transportation, and construction industries are the ones that use and need these composite materials most frequently. The purpose of this study was to look into composite material-produced agricultural machinery equipment and parts. In order to use composite materials in agricultural applications, it was necessary to ascertain which parts or pieces of equipment they may be used in.Here we have to compare steel chaff cutter blades with FRP blades. Stress and deformation for each blade with different blade bevel angle is calculated by FEA.

Keywords-*FEA, stress, machinery, composite*

I.Introduction

A mechanical tool called a "chaff cutter" is used to chop up straw or hay so that it can be mixed together and fed to cattle. By doing this, animals' digestion is improved and they are less likely to reject any portion of their diet. The population of cattle and buffaloes has significantly expanded in the current environment. Motorized machineries were created as a result to boost output and decrease the physical effort needed to operate the equipment; they are ideal for dairy producers. Fodder cutting machines are currently powered by electricity, as well as by hand, engine, or both. This machine can process a variety of fodder, including forage grass, green grass, dry corn straw, and wheat stalk. The finished goods can be utilized to make food.

Additionally, it can process cotton stalks, bark, and small branches, which can be utilized to produce paper and power. Chaff cutters have evolved through time from simple devices to industry standards that can be operated at different speeds to provide a variety of chaff cut lengths depending on the type of animal being used. New chaff cutter equipment includes mobile, tractor-driven models that may be used in the field and load trolleys.

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The current green feed cutting machine can only cut green feed in the form of a rod; it cannot cut green feed into blocks. There is an urgent need for a modern, useful, effective, and environmentally friendly fodder cutter, whether it be for a peasant household, a court, or farms and sales markets. Traditional human-powered fodder cutting machines were utilized for this type of population, although doing so required strenuous physical labor.

Motorized machineries were created as a result to boost productivity and lessen the physical effort needed to operate the machine.

II.Finite element Analysis

The finite element method (FEM) is a popular method for numerically solving differential equations arising in engineering and mathematical modeling. Typical problem areas of interest include the traditional fields of structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential.

The FEM is a general numerical method for solving partial differential equations in two or three space variables (i.e., some boundary value problems). To solve a problem, the FEM subdivides a large system into smaller, simpler parts called finite elements. This is achieved by a particular space discretization in the space dimensions, which is implemented by the construction of a mesh of the object: the numerical domain for the solution, which has a finite number of points. The finite element method formulation of a boundary value problem finally results in a system of algebraic equations. The method approximates the unknown function over the domain. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. The FEM then approximates a solution by minimizing an associated error function via the calculus of variations.

Studying or analyzing a phenomenon with FEM is often referred to as finite element analysis (FEA).

III.Basic concept

The subdivision of a whole domain into simpler parts has several advantages:

- Accurate representation of complex geometry
- Inclusion of dissimilar material properties
- Easy representation of the total solution
- Capture of local effects.

Typical work out of the method involves:

1. dividing the domain of the problem into a collection of subdomains, with each subdomain represented by a set of element equations to the original problem
2. systematically recombining all sets of element equations into a global system of equations for the final calculation.

3. The global system of equations has known solution techniques and can be calculated from the initial values of the original problem to obtain a numerical answer.

In the first step above, the element equations are simple equations that locally approximate the original complex equations to be studied, where the original equations are often partial differential equations (PDE). To explain the approximation in this process, the finite element method is commonly introduced as a special case of Galerkin method. The process, in mathematical language, is to construct an integral of the inner product of the residual and the weight functions and set the integral to zero. In simple terms, it is a procedure that minimizes the approximation error by fitting trial functions into the PDE. The residual is the error caused by the trial functions, and the weight functions are polynomial approximation functions that project the residual. The process eliminates all he spatial derivatives from the PDE, thus approximating the PDE locally with

- a set of algebraic equations for steady state problems,
- a set of ordinary differential equations for transient problems.

These equation sets are element equations. They are linear if the underlying PDE is linear and vice versa. Algebraic equation sets that arise in the steady-state problems are solved using numerical linear algebra methods. In contrast, ordinary differential equation sets that occur in the transient problems are solved by numerical integration using standard techniques such as Euler's method or the Runge-Kutta method.

In step (2) above, a global system of equations is generated from the element equations by transforming coordinates from the subdomains' local nodes to the domain's global nodes. This spatial transformation includes appropriate orientation adjustments as applied in relation to the reference coordinate system. The process is often carried out by FEM software using coordinate data generated from the subdomains.

The practical application of FEM is known as *finite element analysis* (FEA). FEA as applied in engineering, is a computational tool for performing engineering analysis. It includes the use of mesh generation techniques for dividing a complex problem into small elements, as well as the use of software coded with a FEM algorithm. In applying FEA, the complex problem is usually a physical system with the underlying physics such as the Euler–Bernoulli beam equation, the heat equation, or the Navier-Stokes equations expressed in either PDE or integral equations, while the divided small elements of the complex problem represent different areas in the physical system.

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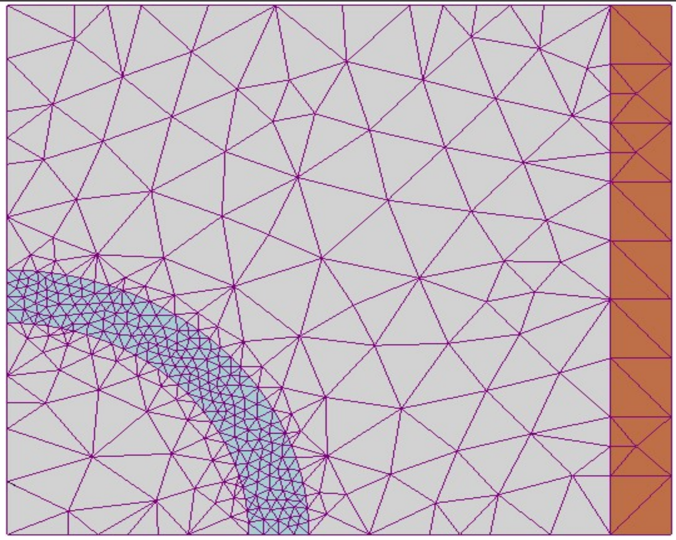


Fig 1.FEM Mesh

IV.Fibre reinforced polymer

A composite material comprised of a polymer matrix reinforced with fibers is known as fiber-reinforced plastic, sometimes known as fiber-reinforced polymer or fiber in American English. Typically, the fibers used are basalt, aramid, glass (for fiberglass), or carbon (for carbon-fibre-reinforced polymers). Other fibers have occasionally been utilized, including paper, wood, boron, and asbestos. Though phenol formaldehyde resins are still used, the polymer is typically a thermosetting plastic like polyester, vinyl ester, or epoxy.FRPs are frequently employed in the construction, automotive, marine, and aerospace industries. They are typically found in self-contained breathing apparatus cylinders and ballistic armor.

V.Load applied on FRP blades- Table 1.Load applied on cutting blades

Material	Load(N)	Angle(Degree)	Deformation (mm)	Von mises stresses(Mpa)
FRP-Steel composite chaff cutter blade	997	10	0.43	178.3
	1337	20	0.59	229.6
	1736	30	0.71	291.5
	2224	40	0.82	328.0

VI.Result and discussion

For 10 degree angle

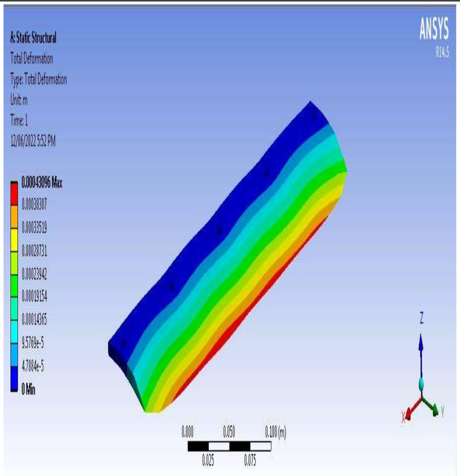


Fig2.Deformation

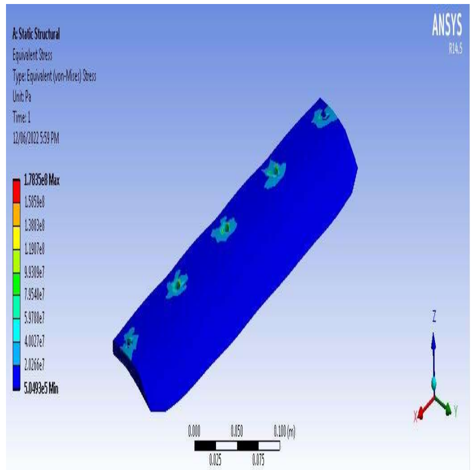


Fig3.Von mises stress

For 20 degree angle

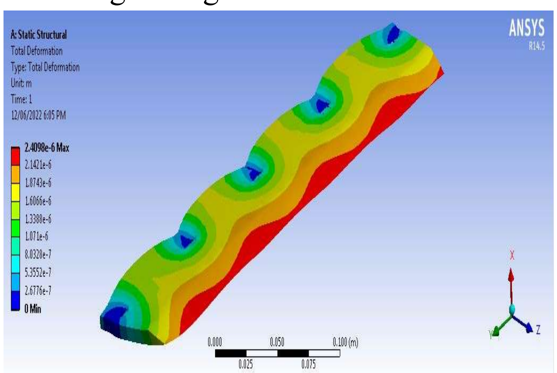


Fig4.Deformation

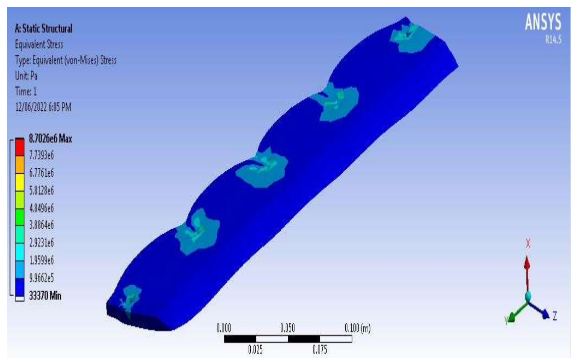


Fig5.Von mises stress

For 30 degree angle

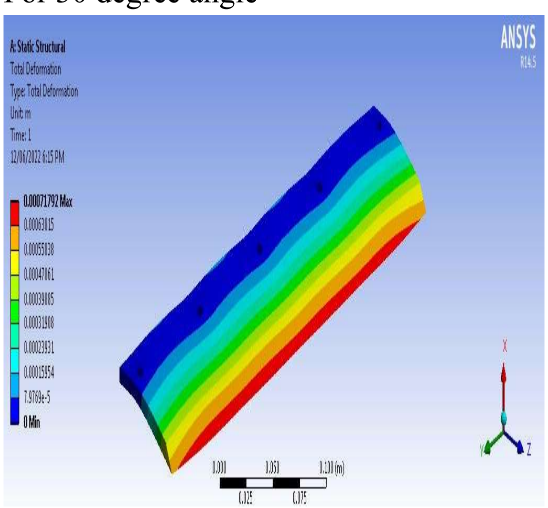


Fig6.Deformation

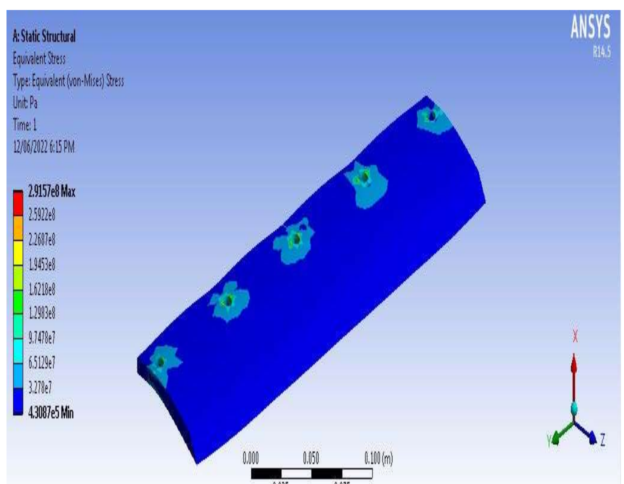
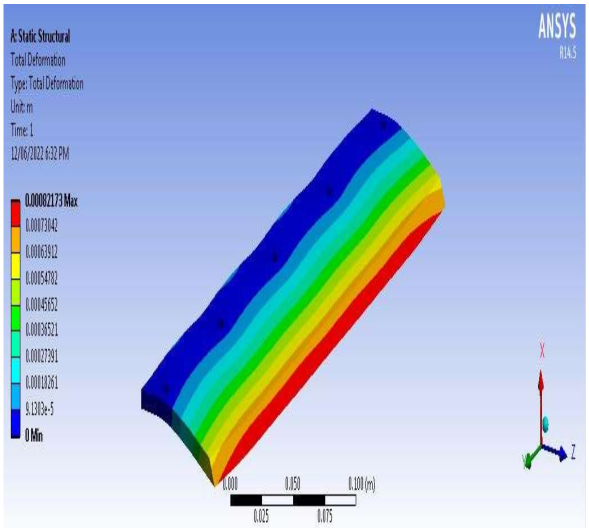


Fig7.von mises Stress

For 40 degree angle



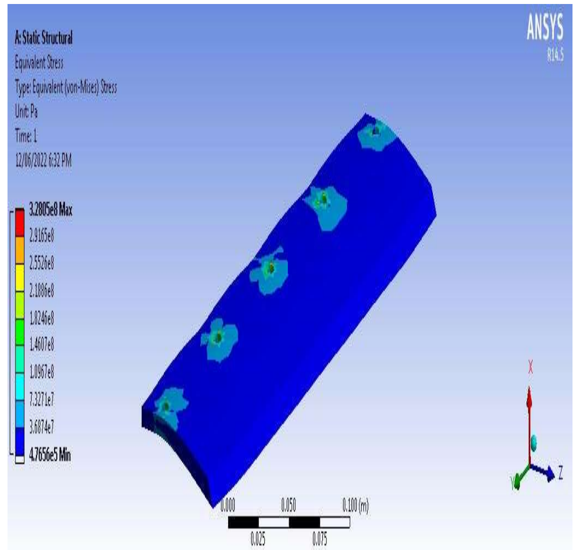


Fig 8.Deformation

Fig 9.Von mises stress

VII.Graphical representation

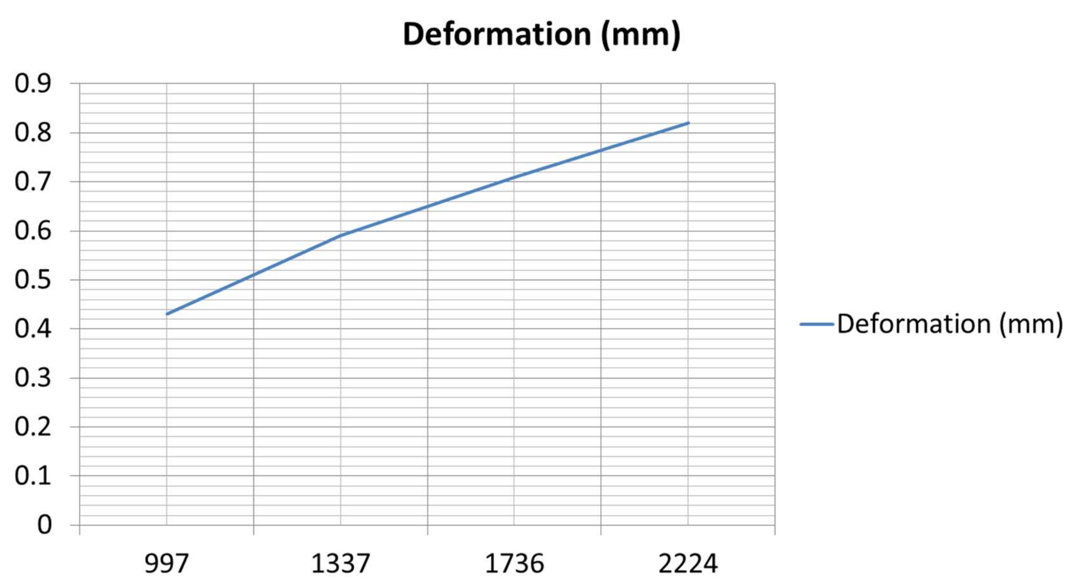


Fig 10. Graph of Load vs Deformation

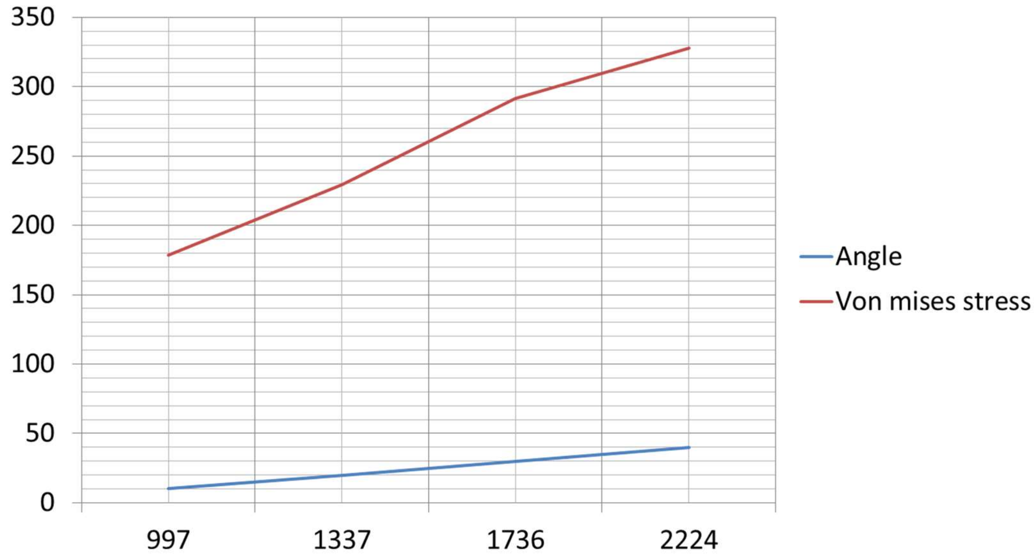


Fig 11.Graph of Load vs Angle and Load vs Von mises stress

VIII.Conclusion

As per result calculated from finite element analysis software, as blade bevel angle increases , the deformation and von mises stresses also increases. So these types of steel FRP blades can be used to cut dry grass as it costs very less. According to the comparison of FRP composite blade and steel blade in terms of draft force, fuel consumption, soil disturbance area, and cone index in the experimental field, and economic comparison between these two blades, FRP composite blade operation was better and more suitable. According to the results of this research in terms of tillage and economic, the use of the FRP composite blade is recommended to farmers and blade manufacturing.

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