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Research Article

Design and Analysis of Tractor Mounted Groundnut Combine Harvester

K. Pradeep Kumar[1], M. Karpagam[*1], S. Sasi[1], P. Sasikumar[1], S. Vanisha[1]

[1]*Department of Agriculture Engineering, Nandha Engineering College, Erode, Tamilnadu, India.*

Cultivation is not fulfilled without perfect harvesting, especially for groundnut. Harvesting and threshing consist of the following operations such as digging, lifting, stripping, and cleaning. Some of these tasks can be eliminated or combined depending on the system applied. In groundnut cultivation the field operation is concerned with threshing and harvesting is the most tedious, laborious, and costly endeavor. Among the field tasks worried about groundnut development, collecting and shifting are the most relentless and exorbitant undertakings. During peak season, the non-availability of labor leads to delays in harvesting results the pods being left in the soil due to the weakening of pegs. Also, late harvesting may expose the crop to field pests which cause substantial loss and it gets easily germinated within the field. Hence, the objective of the present study was to design the tractor-mounted groundnut combine harvester using Solid works software, and the parts which carry more load at harvesting and threshing operation were analyzed such as the digging blade, threshing cylinder by using ANSYS R17.0 for the static structural analysis.

Keywords: Groundnut digger, Groundnut thresher, Solid works, ANSYS, Combined Harvester.

1. Introduction

Peanut is a major oil seed crop. It is the main source of edible oil as well as sesame, cottonseed, and sunflower. Portuguese navigators introduced the crop from Brazil to the western coast of Africa [7]. Across the world, groundnut is the fourth most significant source of palatable oil and the third most significant source of vegetable protein. It was introduced in the 16^{th} century [20]. Peanut (Arachis hypogea) is otherwise called groundnut, it is an interminate and self-pollinating crop [9]. Primarily groundnut is grown under rainfed dry land conditions. Around 67% of total world production comes from semiarid tropics regions [8].

Correspondence should be addressed to
M. Karpagam; kavitha2106karpagam@gamail.com

China is the world's major peanut producer and has a planting area of 4.75x103 Khm^2 with a productivity of 1.7x103 Kt [6].

Groundnut is mostly cultivated in warm climates. It has major two varieties such as bunch and runner variety. The bunch varieties are growing about 30-40 cm in height, but they do not spread. It is common in the United States. Runner varieties are shorter and 30-60 cm in height. They are most common in West Africa [1].

Peanuts are called by multiple local names like earthnut, groundnut, monkey nut, goober pea, pygmy nut, and pig nut. The name of the fruit is called pods, which are grown up to 30-50 cm tall [11]. The dried groundnut crop is an important source of protein in livestock feed. The shells after decorticating are good raw materials for fuel and fertilizer. After oil extraction, the cake is used as livestock feed so that no part of the groundnut is wasted [1]. The kernels or pods or seeds contain 10-20% carbohydrate, 40-50% fat, and 20-50% protein.

AICRP has been released by more than 10 groundnut varieties for different agro-ecological situations in India [15]. Groundnut is a good source of vitamin E, magnesium, Niacin, and Folate.

Harvesting is required when most of the leaves turned yellow and pods become hard [16]. 120-150 days after harvesting is ready for the harvesting operation [9]. The optimum time of harvesting is important so that the maximum yield of the best quality pods with high shelling percentage, high seed mass and high oil content [8]. Due to termites and rodents, the yield loss was estimated at 10-30%.

During late harvesting, pod loss is estimated at 20-30% due to in situ sprouting of pods. Early harvesting can reduce the economic value by about 21% and reduce the yield by about 15% [16]. The present ways of groundnut harvesting are between these three systems – hand, part mechanized, and fully mechanized which are not, of course, clear-cut because simple tools may be used for operating in hand harvesting and hard work need for a fully mechanized system [33]. The time spends on manual or traditional harvesting and threshing method is between 300and 400 hours/ha [10]. If the groundnut is harvested at its correct stage of maturity results the losses greater than 300-450 Kg/ha could ensue [11].

2. Objective

To design the tractor-mounted groundnut combine harvester using Solid works software.

To analyze, the tractor-mounted groundnut combine harvester by using ANSYS R17.0.

3. Traditional Method

3.1. Sowing/Planting

Traditionally sowing operation is done by broadcasting operation and dropping the seed behind the bullocks. But in recent years, it is done along three lines Field Cultivator Piura Method. In the traditional method, 15-20% of losses occurred due to improper germination [32].

3.2. Harvesting

For harvesting, mostly the tuber crops were dug out by using hand tools such as a hoe, fork, etc., [4]. Most small-scale farmers harvest the groundnut crop by pulling it out from the soil at the time of maturity. For digging the use bullock drew or hoes or blade harrows. Under such drought conditions most of the soils, except sandy soil become hard contributing to harvesting problems that severely reduce the digging efficiency [8]. On the previous day of harvesting, the field needs to be wet which results in the soil becoming loose and helps for easy pulling. Once the plants are plucked, the pods need to be separated from the shell [4]. If the soil is wet, the plants are harvested by hand. If the soil is hard and dry, the plant is loosened by hoe. Then the plant is shaken to remove the soil and then it is stooked to dry out. The stooking consists of a grouping of plants with the nuts at uppermost or making as small heaps where no rain will fall at the time of harvest. The plants are stooked round as a single pole or tetrapod or tripod in humid regions where rain is expected [32]. The heaps were left for 2-3 days for curing, later it collected at one place for threshing [20].

3.3. Threshing

Threshing is the process of discrete pods or shells from the plant [14]. The pods were plucked from the plant either manually or by beating the plants against the stone or an iron rod which leads to heavy pod damage [31]. Stripping is done traditionally either by hand or hitting by rods. Both methods are quite difficult. Both will damage the pods and also the fingers. Manual stripping needs 20 to 30 women per day per hectare [4]. The best solution to alleviating labor shortage at peak person, overcoming the climatic changes and achieving the timeliness of operation, and increasing the profit with a reduction in time and cost is to mechanize both harvesting and threshing operation which is a favor to small farmers also [5].

4. Mechanical Method

The agricultural labor emigrates from rural to urban areas, this results in a lack of labor for agricultural processing. It can be rectified by mechanizing both harvesting and threshing operations to increase productivity followed by profit [5].

Mechanical harvesting is necessary to hand over the picking length at the time of operation and reduce the cost by reducing the number of laborers with increased productivity up to several times [10]. There are two methods of groundnut harvesting in the world. The first method has two stages of work such as the vines are dug, shaken, and finally inverted, but the second method does the work in one stage [9]. Mechanical harvesting helps to reduce the losses in stooks or windows and minimize the labor demand and ensure the quality of working and ensure the time of working.

The currently used methods of harvesting groundnuts are equivalent to the harvesting of cereals with a windrower followed by a combined harvester fitted with a pickup attachment. Mechanical harvesting of groundnut is usually lifted, cleaned, and windrowed by a digger-windrower. Light soils permit more efficient cleaning of the plants as the windows form. So, it is more suitable [32]. Many data are necessary for designing various peanut processing equipment's such as special metering devices, planting machinery hoppers, and blades applied for digging peanuts in harvesting machines. A proper adjustment of the shelling machine is necessary to reduce losses in post-harvest equipment [40].

During peak harvesting season, even India faces labor unavailability which results in delays in harvesting and subsequently large losses. Increased mechanization can enable more timely harvest with lower losses and would create a gender shift in harvest workers [17]. The main factors affecting the performance of mechanical threshers are the peripheral speed of the cylinder, moisture content, and type of threshing elements [21]. In mechanical harvesting, 1/5 of labour is needed for mechanical harvesting when compared with manual harvesting [41].

5. Literature Review

Muhammad et al. (2017) have investigated the effect of moisture content on some engineering properties of groundnut pods and kernels. The chief aspects, porosity, true density, point of rest, and static coefficient of contact were found to increment with expanding dampness content of the groundnut independent of the assortment. However, the bulk density decreased with the increase in moisture content for both varieties [1].

Angela. M.A et al. (2021) have developed a local threshing machine for separating and extracting the peanut pods from straw and other materials. This was done by replacing the normal concave with an opening of 7x7 cm per opening (square shape). The front strainer is supplanted with its openings as slides distance of 5 cm, and changing the leeway among curved and sifting drums in the scope of 7 cm (drum 1) and clearance between concave and threshing drums in the range of 5 cm (drum 2). The most threshing proficiency (99.7%) was acquired by drum (2) under 450 rpm drum speed and 15 Kg/min taking care of rate [3].

Ashok. S. Andhale et al. (2017) have designed and developed a groundnut pod separating machine electrically powered by a 1 hp motor. The machine was constructed mainly with the components of the robotic arm and spiked rotating drum. The mechanical arm will cull out the groundnut harvest and take care of it on the spiked alternating drum from the root site of the yield. Spikes on the rotating drum will remove the pods from the groundnut crop. Finally, the picked peanuts are stored at the bottom of the casing. With this, the threshing cost and threshing time are reduced, and the threshing efficiency is improved [4].

P.K. Padmanadhan et al. (2006) have designed and developed a tractor-operated groundnut combine harvester. The combine harvester has to perform dual operations such as harvesting and threshing, the groundnut harvesting mechanism, conveyors and threshing mechanism have to be mounted integrally to carry out harvesting and threshing simultaneously. Thus, the result of the groundnut combine harvester revealed that the maximum harvesting efficiency of 72.30%, threshing efficiency of 82.30%, cleaning efficiency of 72.30%, and minimum percentage of broken pods of 4.43% for model farm hauler worked groundnut consolidate was seen at 1000 mm width of the reaper and 1.5 Km/h forward speed of activity [5].

Afshinazmoodeh- Mishanmandani et al. (2014) evaluated the performance of a peanut harvesting machine in Gilan province, Iran. The result of the machine revealed that by using the minimum conveyor slope at the minimum forward speed the pod's loss can decrease. The digging efficiency is good at 12-15% of moisture content. The maximum harvesting efficiency is 92.3% and unexposed pods loss at 5% [9].

T. Bako et al. (2015) have evaluated the performance of an existing tractor-mounted groundnut harvester. The presentation of the current tractor-mounted groundnut was assessed at various degrees of machine speed (2 km/hr, 3 km/hr, 4 km/hr, 5 km/hr) and a consistent entrance profundity of 10 cm. Harvesting efficiency diminished with speeding up while rate harm sped up. The highest harvesting efficiency (75.3%) was obtained at a 2 km/hr operation speed and the lowest harvesting efficiency (63.7%) was obtained at a 5 km/hr operation speed [18].

A. P. Magar et al. (2010) evaluated a square beater bar type threshing drum on groundnut harvesting. A square beater bar drum-type groundnut thresher was fabricated which mainly consists of a feed hopper, threshing unit, cleaning unit, and power transmission unit. The effect of three plant moisture content on two cylinders was studied for the threshing efficiencies for the cylinder speed of 215 rpm. Cleaning efficiency indicates the presence of foreign matter with a pod in the pod outlet. It was seen that the cleaning efficiency decreased with an increase in plant moisture [20].

P.K. Padmanathan et al. (2007) investigated the influence of the width of the harvester blade (400, 700 and 1000 mm), the peripheral velocity of the picker conveyor (0.95, 1.19, and 1.27 m s^{-1}), and forward speed of plant travel belt conveyor (0.45, 0.55 and 0.69 m s^{-1}) on picking efficiency and conveying efficiency of groundnut harvesting mechanism. Increase in forwarding speed of plant travel belt conveyor which increases the picking efficiency of picker conveyor of groundnut harvesting mechanism. Increase in peripheral velocity of picker conveyor which increases the conveying efficiency of picker conveyor. Also, an increase in the width of the harvester blade increased the picking and conveying efficiency of the picker conveyor [28].

After reviewing the articles, it can be concluded that the techniques are constantly taking the efforts to make the process easier and to reduce the efforts of the farmers. The structure of the machine is common, like the main frame and its attachments. But modifications of various components like blades are tried and improve the results. The main application from both mechanical harvesting system and automatic harvesting systems has been collected. From the literature, mechanical harvesting systems show advantages in mass production but are not suited for small land holders. Most of the common point observed in this study is the speed of the tractor 2km/hr gives better performance, and the appropriate moisture content of 15-25% was at harvesting time and 18-24% at threshing time. Most research came out with the results, that show mechanization of the harvesting process is economical through the initial cost of the machine is high. By improving the efficiency of existing machines and cost reduction, the cultivation of groundnut becomes very simple and can make it easy.

6. Materials and Methods

6.1. Multi Gear Box

The power was transmitted from the tractor Power Take Off shaft (540 rpm) to the multi-Gear box. From the multi-gear box, the power was transmitted to the chain and sprocket mechanism, threshing unit, and cleaning unit by providing a belt and pulley.

6.2. Digging Unit (Blade)

The blade was one of the main components of the groundnut harvester. It is located at the front of the implement. The performance of the blade is depending upon its shape, orientation, and initial soil condition. Here, the flat type of blade is used which can dig two to three rows of the field. The blade can penetrate the soil at the desired depth and get moved back to the conveyer by the forward motion of the tractor. The overall length x width of the blade is 1830x300mm.

6.3. Conveying Unit

Harvesting crops are conveyed by griping the top of the plant between a pair of chains or belts that have followed for so many years for sugar beet. Here chain and sprocket mechanisms are used for conveying. The required power was taken from the multi-gear box using the v-type belt. The plants were drawn through the gap between the pair of chains from the digging part and they were conveyed to the threshing unit simultaneously. The sprockets were attached at both ends of the chains. The length of the chain is 1200mm.

6.4. Threshing Unit

The threshing unit has two main components a rotating cylinder and a sieve.

6.4.1. Rotating Cylinder

Stripping is done by the rotary motion of the cylinder when the plant is conveyed (or) moved through the chain which is placed over the cylinder simultaneously. The rotating motion is used to separate the groundnut from the vines. The vines along with the groundnuts are held over the drum and the pods get removed. At the end of the chain, the vine will be felt on the rectangular plate which is welded with the frame at the end of the implement for throwing out the plant. Drum length x diameter is 1200x300mm.

6.4.2. Sieve

The threshed pods reached the sieves through the hole on the drum. Here is only one sieve plate that has the dimensions of 1300mm in length and 1700 in width. The sieve hole has a 5mm diameter and the hole-to-hole distance is. The pods reached the collecting chamber by providing an outlet at the end of the sieve plate and the soil which is less in size (<5mm) directly fell on the field.

6.5. Collecting Unit

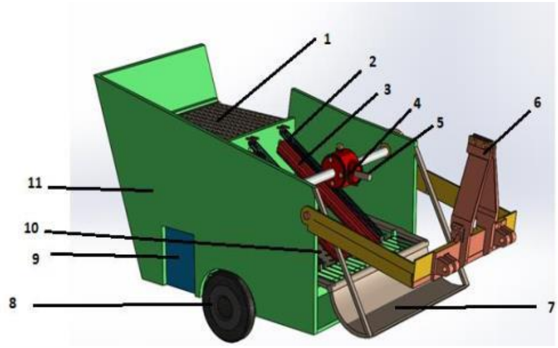
The collection chamber (collection unit) was used for the collection of the separated groundnut after the cleaning process by the sieve. It is provided at the rear side of the conveyor. The collecting chamber is a rectangular box that has a volume. The dimension of the box is 90x1500x120 mm (l x b x h).

7. Working Procedure

The blade penetrates the soil to the required depth and digs out the groundnut plant with pods. After digging, it was conveyed through the gap between the pair of chains. The threshing drum is placed under the chain and sprocket. The rotating cylinder takes the power from the multi-gear box by appropriate belt and pulley power transmission. When the plant conveyed, the pods were separated by the rotating motion of the threshing drum from its vines. Then the pods have reached the sieves placed under the threshing drum. The soil particles and other foreign materials which are too less in size compared with groundnut pods reached the ground by the sieve vibrations. The cleaned pods are collected in the collecting chamber. At the end of the chain conveyor, the plants reached the field with the help of the rectangular plate which is place at the end of the chain conveyor.

8. Analysis

In this paper, Solidworks 2018 version software was used to establish the three dimensional model of the groundnut combine harvester. Solidworks software is a universally useful PC program, which is utilized for creating and dimensioning models for designing purposes in hardware creation. During the phase of making the framework model, each part that needs to analyze was independently displayed and mounted on Solidworks 2018 premium program and they were analyzed by ANSYS 17.0 version software. The optimization analysis and model analysis of ANSYS were administrated for the digging part and threshing part of the implement, especially for displacement and force created by the excavating mechanism and threshing mechanism after the force was applied. As well as the analysis is done on the hitching point of the implement for the vibration analysis when the force is applied while operating.



1. Vine outlet
2. Chain and sprocket
3. Threshing cylinder
4. Multi-gear box
5. Power transmission shaft
6. Hitching hook
7. Flat blade
8. Transport wheel
9. Chamber outlet
10. Sieve
11. Frame

Fig.1. Design of Groundnut combine harvester

8.1. Finite Element Analysis (FEA)

To achieve optimization and model analysis of the digging blade, threshing cylinder, and hitching point, finite element modeling was a very important method. The finite and static analysis is especially used to analyze the deformation and equivalent stress of the digging blade, threshing cylinder, and hitching point of the implement after being loaded. Before rack modal analysis, the parts such as the digging blade, threshing cylinder, and hitching point needed to be meshed to form a unit with a finite number of nodes. Grides of various sizes and shapes have a significant impact on the analysis results.

The meshing platform in the finite element analysis programming can consequently perform meshing as per the design and attributes of the article. It has a variety of methods to divide the meshing platform, such as automatic, tetrahedrons, and hex-dominant. Automatic meshing was utilized to balance computation exactness and estimation time. The divided grid had 66,663 elements and 161,722 nodes.

8.2. Static Structural Analysis

Static structural analysis is the most common type of structural analysis using the finite element method. Static Structural Analysis is used for simple linear, calculations as well as complex material, geometric, and contact nonlinear calculations. A static structural analysis calculates the effect of steady (or static) loading conditions on a structure while ignoring inertia and damping effects, such as those caused by time-varying loads. The analysis results help to identify weak areas with low strength and durability. Based on structural analysis, we recommend modifications of structures such as to meet the defined requirements for strength and durability of the structure.

8.2.1. Digging blade

It is the front part of the implement which is used to loosen the soil. The performance of the blade depends upon its shape, orientation, and initial soil condition. The draft power of the blade is straightforwardly corresponding to the width of the cutting edge and increments dramatically with working profundity.

The function of the digging blade is to dig and loose the soil during the operation, but the resistance of the entire excavation system forward is much greater than the resistance of the single digging blade, so investigation of stress, strain, total deformation, and uprooting of the whole removal framework was performed as per the pressure model and trail analysis of the deep shovel.

The resistance of the blade is affected by the width, depth, dip angle, and soil volume of the blade. The width, length, and depth of the blade have a great influence on the resistance. The material was defined as manganese steel by its young's modulus = $1.1x10^{11}$ Pa, Poisson's ratio = 0.34, Density = 8300 kgm^3, Yield strength = $2.8x10^8$ Pa and Thermal conductivity = 401 $Wm^{-1}C^{-1}$. By applying the pressure and force at 500 Pa and 400 N respectively the deformation occurs at $4.8541x10^{-5}$ m at the tip of the blade which has low thickness compared to the top ad middle portion of the blade, and the deformation requirements of the digging blade were meet the conditions of the use. For the digging blade, the number of nodes is 5042 and the number of elements is 2721 as shown in the Fig 2.

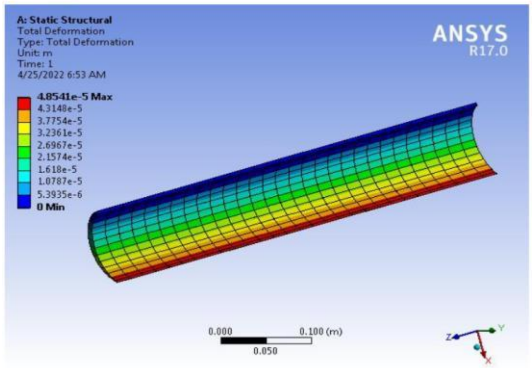


Fig.2. Total deformation map – Digging blade

8.2.2. Threshing cylinder

Using 3D modeling software Solidworks 2018 version we established a three-dimensional slid model of a threshing cylinder. By using ANSYS version 17, finite element analysis was done to solve the vibration characteristics of the threshing cylinder in the unconstrained states, that is, the inherent characteristics in the ideal state[43].

The function of the threshing cylinder is to separate the pods from the groundnut vine by a rotary motion. To obtain an accurate finite element model is necessary to consider the simplification of the model. Therefore, the local features, such as bolt holes, filets, shafts, and far smaller than the mesh size were ignored. The welding flanging, which has little impact on the design and the difference in material properties because of the welding joint, was disregarded[44]. The construction was rearranged as an inflexible association model. The material is defined as gray cast iron by its young's modulus = $1.1x10^{11}$ Pa, Poisson's ratio = 0.28, Density = 7200kg m^{-3} and Thermal conductivity = 52 $Wm^{-1}C^{-1}$. For the threshing cylinder, the number of elements is 1602 and the number of nodes is 3065.

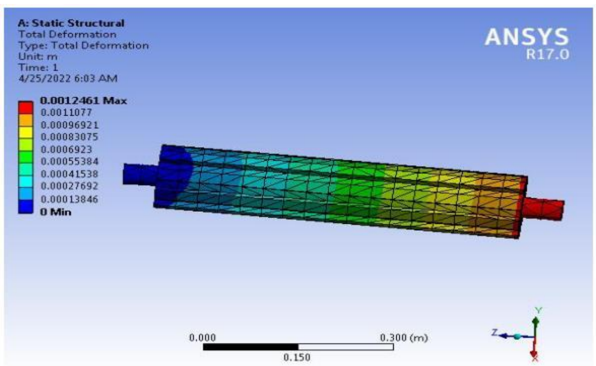


Fig.3. Total deformation map – Threshing cylinder

The moment and load are applied here at 400Nm and 500N respectively. The deformation has occurred. The maximum deformation is 1.2461×10^{-3} m as shown in the Fig 3.

8.2.3. Hitching hook

It is the part of the machine which is used to hang the implement to the prime mover (tractor). The material defined as the stainless steel which has density = 775 kgm^{-3}, Thermal conductivity = 15.1 $Wm^{-1}C^{-1}$, Yield strength = 2.7×10^{8} Pa, Young's modulus = 1.93×10^{11} Pa, Poisson's ratio = 0.31. For the hitch hook, the number of nodes is 3065 and the number of elements is 1602. The pressure is applied on the hitch point at 500 Pa. the deformation has occurred. The maximum deformation is 1.0743×10^{-10} m as shown in the Fig 4.

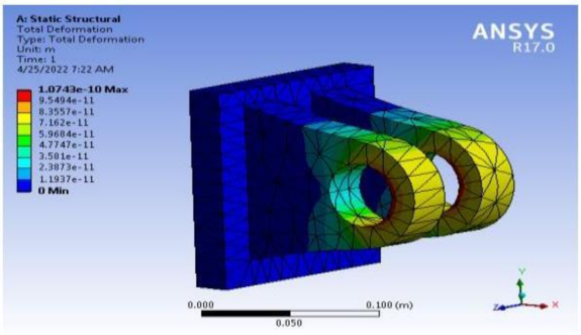


Fig.4. Total deformation map – Threshing cylinder

9. Results and Discussion

The analysis of variance results related to the effects of forwarding speeds, digger angle degrees, and conveyor speeds on the tubers lifting and total damage indexes of a groundnut harvester. As the speed increased, the fluctuation of the digging blade increased and the groundnuts at varying depths got scuffed Based on the small deformation of the existing model in the digger blade. Similar trends of increase in scuffed groundnuts with an increase in forwarding speed of root crop digger have been reported. The pull-type combines for use the engine and the tractor traction[41] to move and drive mechanisms have a lower cost than self-propelled combines, difficulty maneuvering and problems with the coupling system, by the other hand the self-propelled combine presents minimal problems maneuver, the direction easily controls, and the initial cost of acquisition and maintenance. We use a flat blade instead of a V-shaped or another blade. It reduces the damage to pods. The material has maximum deformation of digger blade is 4.8541×10^{-5} m and manganese steel. For digging, the number of nodes is 5042 and number of elements is 2721 and the digger angle is 22°.

The drum of the threshing cylinder was meshed according to the finite element method. It was found that 3065 nodes and several elements 1602 were formed. The analysis was performed that found young's modules = 1.1 $\times 10^{11}$ Pa, Poisson's ratio = 0.28, and thermal conductivity = 15.1 $Wm^{-1}C^{-1}$, and the material we used was grey cast iron.

The finite element static analysis is mainly used to analyze the deformation of the digging blade, hitching hook, and threshing cylinder when is undergone load. After accomplishing the pre-processing, the ANSYS workbench toolbox will automatically estimate the blade, hitching hook, and threshing cylinder. The total deformation of the digging blade, hitching hook, and threshing cylinder were in Figures 2, 3, and 4 respectively. In the blade, the maximum equivalent strain solution was 4.8541×10^{-1}m, as shown in Fig. 2. The maximum equivalent strain solution was 0.0012461m for the threshing cylinder as shown in Fig. 3. And also in the hitching hook, the maximum equivalent strain solution was 1.0743×10^{-10} m as shown in the Fig. 4.

10. Conclusion

The combine harvester for harvesting and threshing the groundnut for all scale farmers was designed and tested using the Solid works software program. ANSYS software was used to analyze the total deformation of the digging blade, threshing cylinder, and hitching hook of the combine harvester. The maximum deformation for the hitching hook, digging blade, and the threshing cylinder was 1.0743×10^{-10} m, 4.8541×10^{-5} m, and 1.2461×10^{-3} m respectively. By testing the parts by static structural analysis, the deformation is defined when the load, pressure, and moment are acted during the operation. So that, we can find how much amount it is strengthened. Here the digging blade tip gets the maximum deformation, while the pressure and force act at 500 Pa and 400 N respectively. Because of the depreciation occurring at the blade, the efficiency of the blade decreases. At this exact time, it is far easier to replace the blade.

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