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RESEARCH ARTICLE

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A REVIEW ON DESIGN ANALYSIS OF ROTOR PIPE (SHAFT) OF 5-FEET RAJ ROTAVATOR

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Abstract

The rotavator is important agricultural equipment that plays a major role in seedbed preparation. Seedbed preparation is done by the tillage of the soil. Typical 5-feet raj rotavator models, having a progressive cutting sequence are considered for the study and analysis. The purpose of this paper is to study the various forces and stress acting on a rotor shaft assembly of a standard 5 feet raj rotavator that is under various loading conditions at different time intervals and at different speeds. The study was carried out on different papers and identifies the various forces acting on a Rotor shaft of a rotavator. Within this paper, the analysis is done on the existing rotor shaft assembly of a 5-feet raj rotavator, and it is found that the force acting on the per flange on the rotor shaft is 545.13 Newton, with a torque generated at the rotor shaft is 752.29 N-m. so that will be helpful future to the modified design of rotor shaft with more allowable stresses.

Introduction:-

Automation in the industry gains more value and popularity as it helps reduce costs and time with increased productivity and quality, automation is becoming more and more popular in the agricultural sector as well. This has led to the provision of world-class resources for agricultural crops from planting to harvesting to storage. Farmers usually take two or more crops a year. In a successive planting program, a seedbed is needed to prepare next harvest. Rotavator is a special tractor-operatedtool that uses rotating power to plow the soil (i.e., tillage of soil), to produce a good seedbed for plants. While Rotavator destroys the weeds, stubbles of paddy, and sugarcane completely. The process of tillage increases Porosity and air permeability which promotes crop growth. One of the additional advantages of using a rotavator is that it provides some forward thrust thereby reducing the traction demand of the tractor [1]. Compared to a standard plow the amount of energy required is low. It is the most efficient way to transfer engine power directly to the ground compared to the normal operation of ground tillage [2]. Compared to the rotavator plow type, the rotating type consumes 25% less energy [3]. Normally engine power is supplied to the rotavator using a PTO shaft tractor. Rotary movement and transmission to the rotor via gearbox and transmission system. Flanges are attached to the rotor where the cutting blades are attached.

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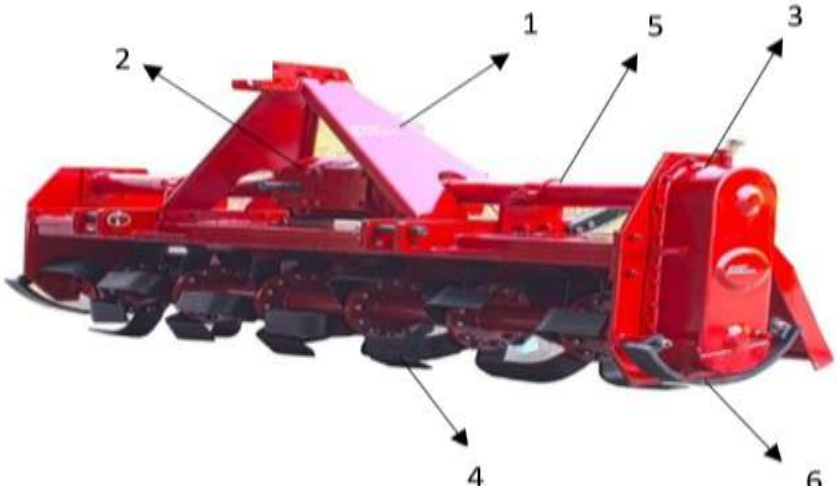

Figure 1:- 5-feet Raj rotavator (factory-site captured picture).

Following are the main parts of 5 feet raj rotavator as shown in figure 1,

1. Independent topmast: It is used to attached the rotavator and tractor rigidly. The attachment is done by attaching the top link of the tractor to the topmast of the rotavator.
2. Primary multi-speed gearbox: the primary gearbox assembly consists of bevel gears, main shaft, pinion shaft, and heavy-duty roller bearing. It is used to reduce the P.T.O rpm transfer from tractor to rotavator.
3. Secondary gearbox: It consists of 3 gear arrangements inside which reduces the future rpm at the input to the rotor shaft assembly.
4. Rotor shaft assembly: Within the rotor shaft assembly the blades are attached on flange and flanges are attached on the rotor shaft.
5. Flange shaft: flange shaft is used to transmit power from the primary gearbox to the secondary gearbox.
6. Adjustable depth skids: It is fixed on an adjustable frame to fix up a distance gap between soil and Blade contact i.e., depth skid.

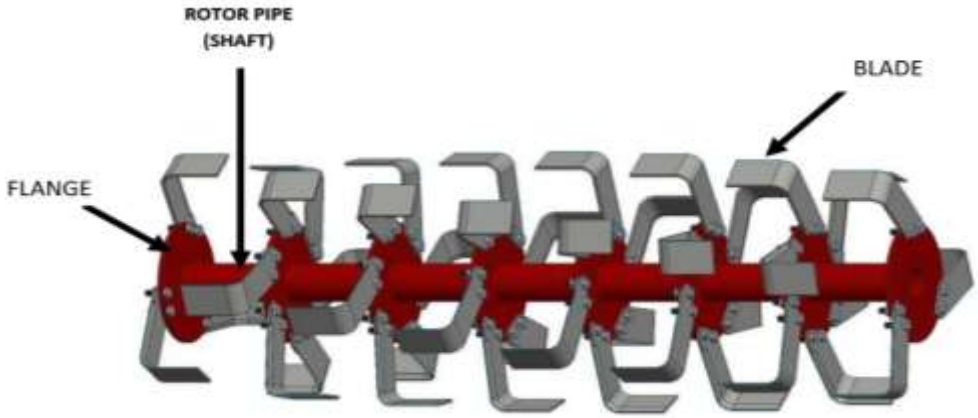

Figure 2:- Rotor shaft assembly of 5-feet Raj rotavator (Mr. S. A. Mishra, 2015).

Literature Review:-

To study the earlier work that has been carried out related to the topic and also to get an idea regarding the topic or related to topic from research papers, books, etc., the literature survey has been carried out. A comprehensive literature review of some selective research papers has been elaborated on below,

1. Mr. Stephen K. Armah, (2018) has made a study on power transmission shaft under fatigue loading using ASME code. In their study, they had presented a comprehensive fatigue analysis approach of determining the initial dimensions of a power transmission shaft under fatigue loading based on American Society of Mechanical Engineers (ASME) Standard B106.1M:1985. And different pressure analyses in potentially sensitive areas are performed to determine shaft sizes. Sizes from these areas are then used to measure sizes

in areas of low pressure. With the help of this, the countershaft is a design that moves at the speed of the counter. And to visualize the future a CAD model is designed.

2. Mr. Vignesh. M. and Dr. Muruganandhan,(2015) have studied the torsional response of the rotor shaft of a standard rotavator which is subjected to transient loading conditions. Within the analysis of the standard model, the progressive cutting sequence is considered. The study was extended future on five different cutting blade arrangement models. The study was carried out by applying varying cyclical torque at different intervals of time on every flange position on the rotor shaft. The positions of the torque applied are varied according to the model considered. The transient response of the system was obtained using ANSYS Workbench. The response was obtained by considering the angle of twist and equivalent stress on the rotor shaft.
3. Mr. S. A. Mishra, et. Al, (2015) has made a study on the flanges that are attached to the rotor shaft. In this study, the various reasons were identified and the existing rotor assembly were being analyzed by doing the modeling and carrying out ANSYS analysis. Within the study, the major calculation was been done on the flange and after analysis, it is been concluded that the material for the flange is not proper to withstand the different types of forces incurred on it. Therefore, new material EN 19(oil Quenched & drawn) has been suggested.
4. Prof Srinivasan. K and Prof. Viswanath R. P researched rotavator blades. The purpose of their research is to design and make the Rotavator Blade have a better life and be more efficient on the field. Therefore, any improvement in the performance of the same field can also increase productivity in the agricultural sector. Within the study they had various kinematic and static analysis statistics on rotavator blades and various soil areas were also analyzed by the appropriate failure model and finally described the effect of flexible analysis of rotavator blades during planting using soil. FEA Abaqus tool.
5. Ms. Subrata Kr. Mandal (2013) also conducted research on the rotavator blade. The purpose of the study is to develop a rotavator blade with a good life. In Rotavator, Blades are important parts which engaged with soil for preparation of soil bed. These blades interact with the ground differently than conventional impact plows and high collisions causing uneven and uneven forces causing blade aging. This shortens the service life of the blade. Therefore, it is necessary to design and develop a suitable blade for personal life to be improved. His research also took the form of computer-aided design (CAD) into blade design and development accounts.
6. Mr. D. Ramesh Kumar and Mr. P. Mohanraj (2017) conducted research on rotavator blades based on simulation and the method of measurement was performed using the ANSYS software. In this study, the author's analysis of the current functional geometric model with a tillage blade and a change in the new boundary design was proposed and operated as a result of the analysis from field performance.

Problem Identification: -

It has been observed that the rotor shaft assembly of the 5-feet raj rotavator gets failed at the various loading condition from the flange joints. The flange also gets deformed due to the colloidal of the blade on hard obstacles. After reviewing various research papers on rotavators and considering the working condition under which the rotavator is going to use, in this paper to prevent the failure of the rotavator during operation, the author is trying to find out the critical parameter to be considered for proper designing of rotavator.

Figure 3:- Breakdown in rotor shaft (factory-site captured picture).

Figure 4:- Deformation of flange (Mr. S. A. Mishra, 2015).

Methodology:-

The methodology will be as follows:

Study of existing rotor shaft assembly in rotavator:
Firstly, a study of the existing rotor shaft assembly of 5 feet raj rotavator will be carried out, within which all the existing specifications of rotor shaft will be studied that will be necessary to calculate the parameters like forces on rotavator blades, forces on rotor shaft while in rotation, and soil forces that act on rotor blade while in working.

Design calculation for the new modified design:
After analysis of the existing design, the failure of the existing design will be found. And new rotor shaft will be designed which will have more allowable stress than the calculated value of the existing design of the rotor shaft.

Preparation of CAD model:
The CAD model of the modified design will be made as per the specification calculated within the modified design.

Modeling and analysis of modified rotor shaft.
The same CAD model of modified design is the analysis using the ANSYS software that values will be matched will the design calculation values of the modified design.

Result And Discussion:-

In the end, the existing and modified design will be compared on the basis of analysis performed and better-achieved performances values will be discussed future.

Design Calculation: -
Study of existing rotor shaft assembly in rotavator:
Firstly,For calculating the force and stress acting on the rotor shaft and flange and blade, the specification of tractor and rotavator has been studied. The present 5-feet raj rotavator has been selected for study and its specification are as follow.

Nomenclature Table:

Parameter	Description
T	Torque
V	Velocity
F	Force
P	Power

Unit	Description
m	Meter
m/min	Meter per minute
HP	Horsepower
N	Newton

N-m	Newton meter
KW	Kilowatt

General specification of rotavator:
The following table shows the specification of the rotavator

Sr No.	Parameter	Description
1.	Size of rotavator	5 Feet (1.5 m)
2.	Speed of rotor shaft	195 Rpm to 214 Rpm
3.	Type of rotor axle	Tubular cross-section
4.	Length of rotor shaft	1470mm
5.	Number of blades	36
6.	Tractor required to drive rotavator	45 HP to 50HP
7.	Number of flanges	6

Calculation of existing raj 5-feet rotavator:
Assumption
1. The design calculation is carried out by considering the above specification of the rotavator.
2. Tractor which is used for doing the calculation is of Capacity 45HP @ 2300 RPM.

(1) Time Required for Processing of Land
A Medium size Rotavator Process 0.45 Hector area in 1 hour i.e., 60 min.
Therefore, the total time for processing of **4500Sqmt area** is **3600 Secs.**

Figure5:- Land Area Preparation.

(2) Velocity Calculations
No. of rounds required for a medium size Rotavator = 45 / 1.5 = 30 No
Now, distance travelled by the Rotavator in one run = 100 m
Therefore, total distance travelled by the Rotavator = 30 × 100 = **3000 m**

Velocity of tractor (V) = Distance Travelled / Time Taken
= 3000 / 3600
= 0.833 m/s.
= 49.98 m/min.

(3) Power Required for Work done
For the use of a standard medium size Rotavator a 45 HP tractor is required. Therefore, the engine power of the Tractor = 45 HP.

Considering 20% Transmission losses, therefore power available at PTO shaft = 36 HP.
Therefore,
Final power required for the implementation = Power at PTO shaft – Power required for propulsion of tractor

Now,
Value for propulsion power required for the propulsion of 45 hp tractor is 10 HP-from reference paper (3)
Therefore, the power required to drive the Rotavator = Power at PTO shaft – power for the propulsion of tractor.

= 36 -10
= 26 HP
= 19.38 KW.

(4) Torque & Force Calculation

Now, the Torque generated at the Rotor shaft (T) = $\frac{60P}{2\pi N}$ = $\frac{60\times19.38\times10^3}{2\pi\times246}$ = **752.29 N-m**

Now,

Outer dimeter of flange is 220mm and perpendicular length of blade from outer diameter of flange to soil is 10cm.

Therefore, total perpendicular distance from center of rotor shaft to soil is **0.230m = R**

Therefore, Force acting on blade due to torque (F) = Torque / R

= 752.29 / 0.230

= **3270.82 N**

Within the 5 feet raj rotavator there are 6flanges mounted on rotor pipe and a total of 36 blades mounted on 6 flanges.

Therefore, force acting per flange = 3270.82 / 6 = **545.13 N**

Result:-

From the above analysis, it is found that the force acting on the per flange on the rotor shaft is 545.13 Newton, with a torque generated at rotor shaft is 752.29 N-m. so future rotor shaft and flanges will be designed which will have more allowable stress than the above-calculated value.

Conclusion:-

After conducting a detailed literature review it is observed that so many authors had studied the rotavator for design optimization of it. They had also considered the depth of the cut effect, the rotational speed of rotor shaft, forward speed and width of cut cover by blades on the torque requirement, arrangement of blades on flanges of the rotor shaft, etc. But within papers, the authors had given less consideration to torsional response& the various transient loading condition that occur on the rotor shaft of the rotavator under its working condition at a different time interval. The study of torsional vibration and forces is of at most importance because it can result in gear wear, gear tooth failure, shrink fit slippage, and can even lead to the failure of the rotor shaft in several cases. Within this paper the author has found out torque generated at the rotor shaft i.e.,752.29N-m, also force acting per flange is 545.13N. So this paper will be of great help to designers to do well for design optimization.

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