

# **Study of Torsional Response on the Rotor Shaft of a Rotavator under Transient Load Conditions**

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**ABSTRACT:** The intent of this paper is to study the torsional response of a rotor shaft of a standard rotavator which is subjected to transient loading. A standard model, having a progressive cutting sequence was considered for the analysis. The study was extended to five other models having different cutting blade arrangement. The study was carried out by applying a cyclically varying torque at different time intervals on every flange positions of the rotor shaft. The positions of the torque applied is varied according to the model considered. ANSYS Workbench was used to obtain the transient response of the system. The response was obtained by considering the angle of twist and equivalent stress on the rotor shaft. This paper presented a methodology for conducting transient analysis of rotor shaft of a rotavator.

**KEYWORDS.** Rotavator, Angle of twist, Transient analysis and Cutting sequence

## **I. INTRODUCTION**

Rotavator is an agricultural machinery, used to perform primary and the secondary tillage operations in farm. That is it is used to agitate the soil as well as to produce a good seed bed for crops. In the process it increases the porosity and aeration of the soil which enhances the germination and growth of the crops. One of the added advantage of using rotavator is that it provide some forward thrust there by reducing the traction demand of the tractor [1]. When compared to conventional plows, the labour cost requirement is less even though the total power requirement is lower. It is the most efficient means of transmitting engine power directly to the soil when compared to conventional tillage operations [2]. In comparison with that of the plough type rotavator, the rotary type consumes 25% less power [3]. Usually the power from the engine is given to the rotavator through the tractor PTO shaft. Rotary motion is then transferred to the rotor through gearbox and transmission system. Flanges are mounted in the rotor on which cutting blades are attached. Even though, there are studies regarding the effect of depth of cut, rotational speed, forward speed and width of cut on the torque requirement,[4-5] no studies using finite element methods have been conducted on torsional response on the rotor shaft of rotavator under transient load conditions. The study of torsional vibration is of at most importance because it can result in gear wear, gear tooth failure, shrink fit slippage and can even leads to the failure of the shaft in severe cases [6]. Since no other study in this field is available, this paper will be of great use to the designers and also for design optimization.

## II. ROTOR-BLADE MODEL

A typical model of a rotor blade assembly is shown in figure 1. This model is taken as the base model and its specifications are as given in Table1. It consist of six flanges and six blades are attached to each of them, three left hand side and three right hand side blades. The flanges are oriented in such a way that the same side blades of adjacent flanges are 10° apart. The cutting action proceeds in a progressive manner from right to left. The number of blades that are active during a tillage operation depends on the depth of cut required and the distance of its cutting edges from the center of the rotor. For the model considered, the cutting edges are at 225 mm from the center of the rotor and the depth considered is 150 mm thus from the geometric calculations it can be seen that a total of six blades are in contact with the soil at all the time. The model considered thus will have torque acting on all the six flanges at all the time.

### FEM model:

To obtain the torsional response of the rotor, the forces acting on the blades can be replaced by torque acting on the rotor at places where the flanges are mounted. Thus the FEM model of the Figure1 can be modelled as in figure 2. When the cutting order is changed, only the position of torque application is be changed. .

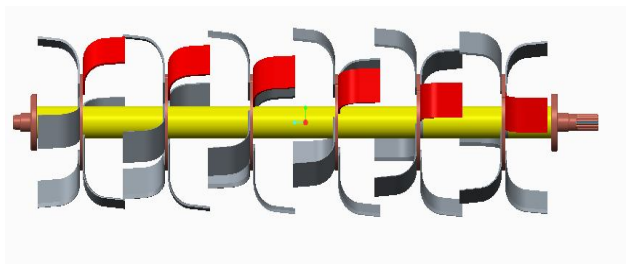


Figure1: Standard blade arrangement



Figure 2: FEM model

Table 1: Rotor specifications

No:	Parameter	Specification
1	Working width of rotavator (mm)	1750
2	Shape of the blade	L-shape
3	Orientation of blades (degrees)	10
4	Length of blade along flange (mm)	160
5	Length of blade along rotor shaft (mm)	135
6	Thickness of blade (mm)	6
7	Distance between consecutive flanges (mm)	280
8	Total number of flanges	6
9	Number of blades per flange	6
10	Outer diameter of Rotor shaft (mm)	76.2
11	Inner diameter of the Rotor shaft (mm)	64.2

## III. FINITE ELEMENT ANALYSIS

### Loads and Boundary Conditions:

The rotor is supported by two bearing on either end and the transmission gear is attached to the splined shaft on the right. Thus frictionless support is given to either ends to simulate the bearing behaviour and a fixed support is given to the splines. The meshed model with boundary conditions is as shown in figure 5.



Figure 3: Meshed model with boundary conditions

The load acting on the rotor can be considered as a sinusoidal one. The model considered have a 12 cm tilling depth, 210 r/min rotational speed, 0.069 m/s forward speed and 13.5 cm blade width. Thus the maximum amplitude torque can be taken as 400 N-m [7]. The cutting edges of the rotor are at a radius of 22.5 cm from the center of rotor shaft thus each blade have to rotate 62.188° from the instant it touches the ground to complete the cutting action. Thus the torque acting on the rotor shaft during the cutting action of a single cutting blade is given by the equation [1] and each torque acts for a duration of 0.04935 seconds.

$$\text{Torque} = 400 \times \sin(63.6594 \times \text{time}) \quad (1)$$

The torque curve is as shown in figure 4. Since two successive cutting blades are oriented 10° apart, there is a time lag of 0.007936 seconds between them.

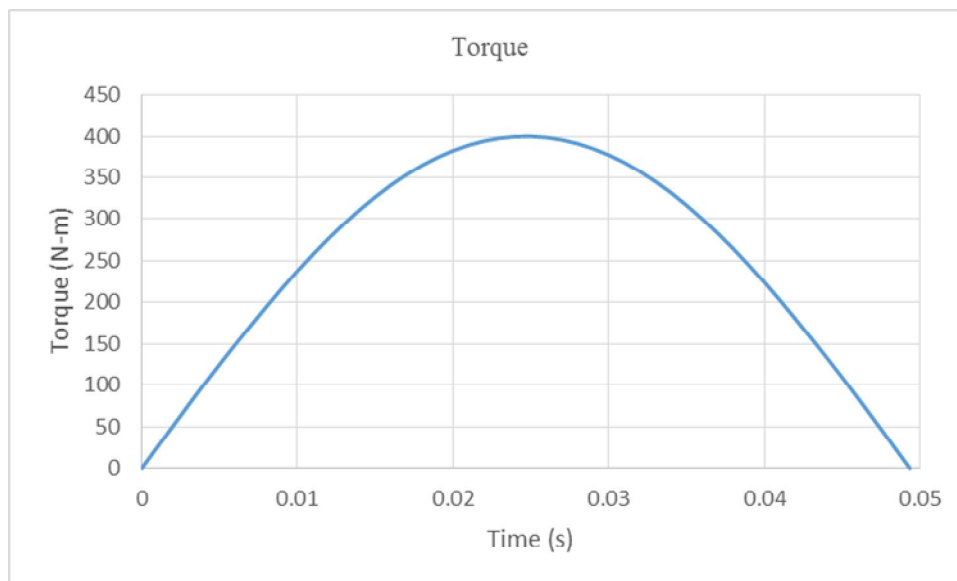


Figure 4: Torque curve

Torque was applied at faces where the flanges are mounted at time intervals corresponding to the cutting sequence in the model. The model shown in figure 1 is taken as the standard model and five other models is shown in figure 5 where the active cutting blades at a time is shown in red colour. The same sequence is been repeated as the blade rotates.

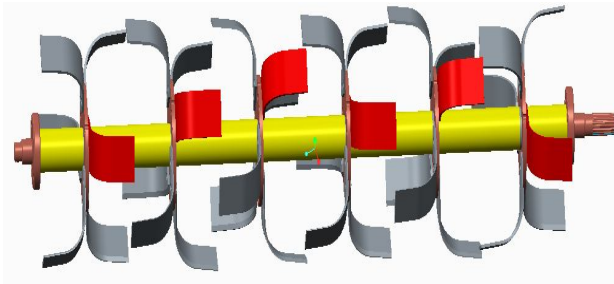


Figure.5.1: Model 1

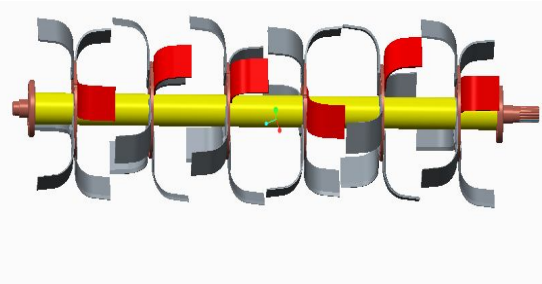


Figure.5.2: Model 2

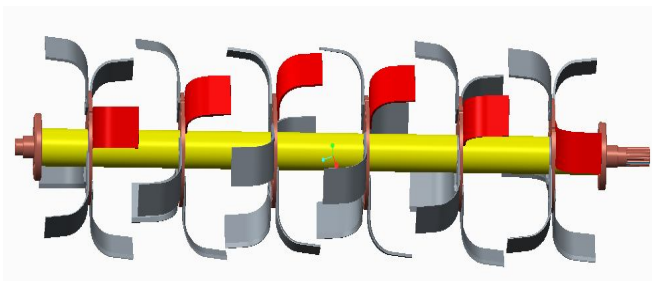


Figure.5.3: Model 3

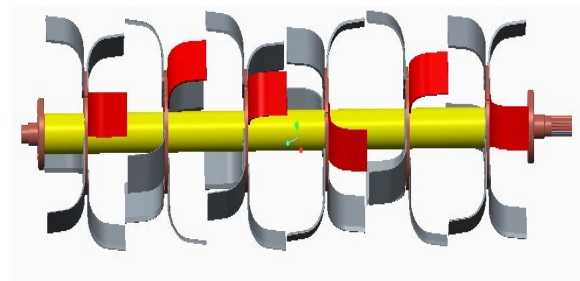


Figure.5.4: Model 4

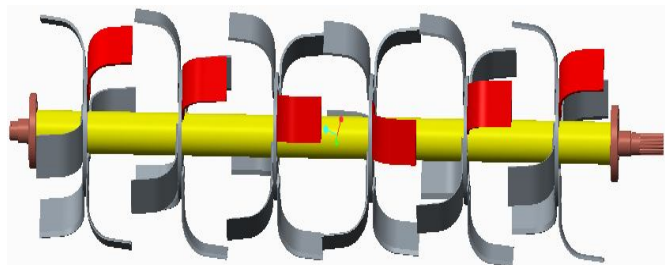


Figure.5.5: Model 5

Figure.5: Blade arrangement of the five model considered

The right end flange is taken as the base and all other flange are oriented from this flange. All the flanges are numbered in a sequential order from right to left. The configuration of all the flanges are as given in table 2.

Table 2: Orientation of flanges

Model	Orientation of flanges (degree)					
	Flange 1	Flange 2	Flange 3	Flange 4	Flange 5	Flange 6
Standard model	0	10	20	30	40	50
Model 1	0	30	50	20	40	10
Model 2	10	50	30	0	40	20
Model 3	0	20	40	50	30	10
Model 4	10	40	0	30	50	20
Model 5	50	30	0	20	40	60

## V. RESULT AND DISCUSSION

Since there are six active cutting blades at any time, to include the effect of previous cutting blades, the reading are considered from seventh onwards. From the analysis, it was found that in comparison with standard model,

the peak value of the angle of twist and equivalent stress was lower in case of model 2. The variation of these values with respect to time for model 2 is as shown in figure 6 and figure 7 respectively.

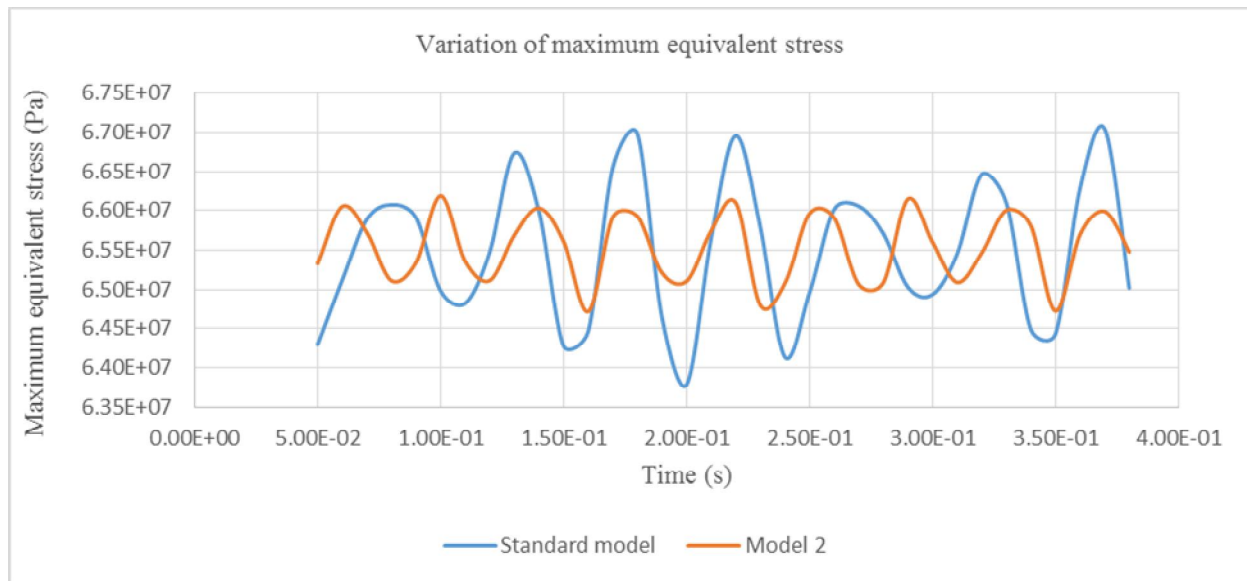


Figure 6: Variation of maximum equivalent stress of model 4

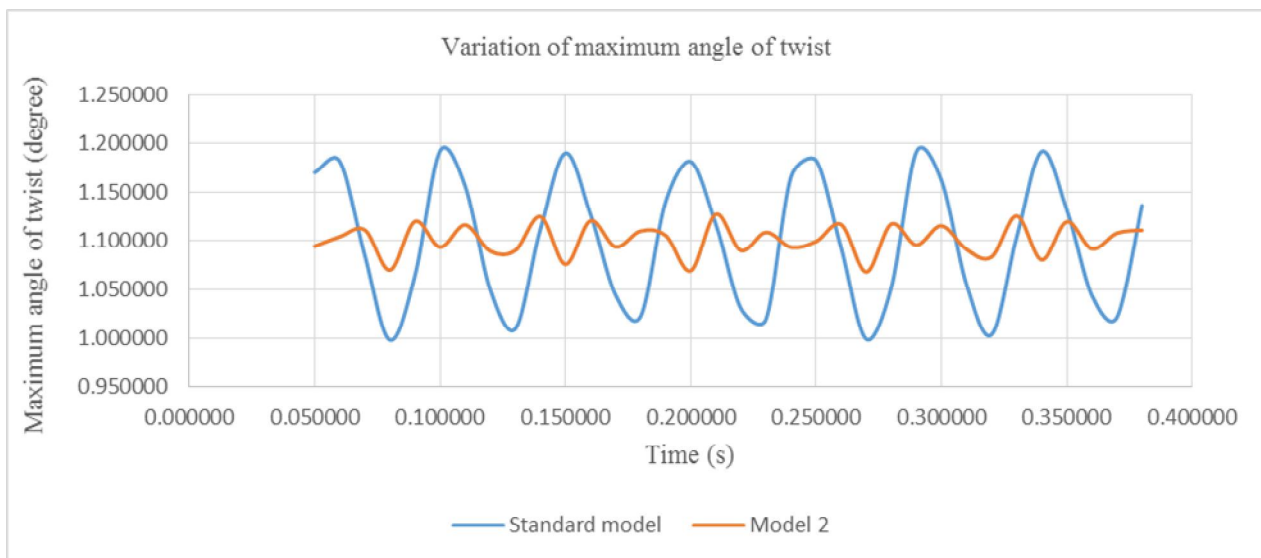


Figure 7: Variation of maximum angle of twist of model 2

The peak value of maximum equivalent stress and maximum angle of twist of all the model is given in table 3. The study shows that the maximum equivalent stress and maximum angle of twist depends on the cutting sequence of the blade. It can be seen from the graphs of maximum equivalent stress and maximum angle of twist that they follow a cyclic variation. This might be due to the nature of the torque acting on them. It is seen that the maximum value of angle of twist occur in the case of the standard model and model 5 has the highest stress value. Another observation that can be drawn from the table is that the variation of maximum value of shear stress is not much while the variation of maximum angle of twist is drastic with respect to change in the cutting sequence.

Table 3: Maximum equivalent stress and maximum angle of twist

	Peak value of Maximum equivalent stress (MPa)	Percentage change in Peak value of Maximum equivalent stress value (%)	Peak value of Maximum angle of twist (degree)	Percentage change in Peak value of Maximum angle of twist value (%)
Standard model	66.979	-	1.192	-
Model 1	66.600	0.565 % fall	1.150	3.523 % fall
Model 2	66.187	1.182 % fall	1.127	5.453 % fall
Model 3	66.262	1.070 % fall	1.143	4.110 % fall
Model 4	66.200	1.163 % fall	1.146	3.859 % fall
Model 5	66.410	0.849 % fall	1.128	5.369 % fall

## VI. CONCLUSION

From the discussions above, following conclusions are drawn.

1. The shear stress and angle of twist variation of all the model reveals that they follow cyclic variation.
2. The cutting sequence does have an influence in the torsional response of the rotor.
3. The cutting sequence have little effect on the equivalent stress but it effects the angle of twist is slightly higher.
4. The cutting blade arrangement of the standard rotavator considered is not arranged according to an optimum sequence.
5. The angle of twist can be reduced by the proper selection of cutting sequence.
6. The torsional rigidity of the shaft can be increased by proper selection of cutting sequence.

## REFERENCES

- [1] Beeny. J. M and Khoo D.C.P, "Preliminary investigations into the performance of different shaped blades for the rotary tillage of wet rice soil", J. agric. Engng Res. (1970), 15 (1), 27-33.
- [2] Jeevarathinam.A and Velmurugan.C, "Design Modification and Analysis of Rotavator Blade", Mechanical Engineering, Kumaraguru College of Technology, Anna University, India.
- [3] Myoung H.K, Ju S.N and Dae C.K, "Comparison of Tillage and Loads Characteristics of Three Types of Rotavators: Rotary-type, Crank-type, and Plow-type", J. of Biosystems Eng. 38(2):73-80. (2013. 6).
- [4] Desa A, "A Width of Cut Analysis on the Performance of a Rotary Strip Tiller - Department of Power and Machinery Engineering", Faculty of Engineering, Universiti Pertanian, Malaysia, Pertanika 9(1), 7 - 15 (1986).
- [5] Ghosh B.N, N. (1967). The Power Requirement of a Rotary Cultivator J. agric. Engng Res. (1967) 12 (1) 5-12.
- [6] Wachel J.C, Analysis of torsional vibration in rotation machinery, senior project engineer, Engineering dynamics incorporated, Texas.
- [7] Sirisak C, Tanya N (2010), Variations of torque and specific tilling energy for different rotary blades, International Agricultural Engineering Journal, Vol. 19, No. 31