Design and Analysis of Rotating Bucket Arm of Excavator

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Abstract – In this paper an attempt has been made to design and analyze the rotating bucket of the excavator along with the stick and the bucket arm. This paper focuses on the joint design by using the geared motor for angular rotation of the bucket arm and studies the effect of digging, torsional force and bending stresses developed on the joint. Study the motion of the bucket arm

Keywords – joint design, motion.

I. INTRODUCTION

Rapidly growing rate of industry of earth moving machines is assured through the high performance construction machineries with complex mechanism and automation of construction activity. Backhoe excavators are widely used for most arduous earth moving work in engineering construction to excavate below the natural surface of the ground on which the machine rests. Hydraulic system is used for operation of the machine while digging or moving the material. An excavator is comprised of three planar implements connected through revolute joints known as the boom, arm, and bucket, and one vertical revolute joint known as the swing joint. The kinematics of an excavator provides only linear motion to the arm[1]. these motion is created by the hydraulics ram. The useful task of backhoe hydraulic excavator is to free and/or remove surface materials such as soil from its original location and transfer it to another location by lowering the bucket, digging, pushing and/or pulling soil then lifting, swinging and emptying the bucket.

The bucket of an excavator plays an important role in the process of excavation. To save the time and power rotating bucket is design and also to increase the excavation area. The designing of joint in the excavator which facilitate the rotation of the bucket along with the bucket ram and the stick. The rotating bucket avoids repositioning which save time and power which increase the rate of productivity.

II. DESIGN REQUIREMENTS

1. Three dimensional model of the arm.
2. The designed joint must withstand the reaction force developed and weight of the arm.

2.1. Material

An aluminum alloy was used in order to reduce the weight of the model, this change lightens the components of the arm [10], allows to increase the load capacity of the bucket and so it is possible to increase the excavator productivity per hour. The joint is made of carbon steel used in the machinery. [6]

III. FORCES

Fig. 1

Determination of digging forces

Fig. 1 shows the measurement of bucket curling force FB, arm crowd force FS, the other terms in the figure dA, dB, dC, dD, dD1, dE, and dF shows the distances as shown in Fig. 1.

According to SAE J1179: Maximum radial tooth force due to bucket cylinder (bucket curling force) FB is the digging force generated by the bucket cylinder and tangent to the arc of radius dD
Where \( \text{DB} \) is the end diameter of the bucket cylinder in (mm) and the working pressure is \( p \) in MPa or N/mm\(^2\) and other distances are in mm and remains constant. Above Equation determines the value of the bucket curl or breakout force in N. Now let us determine the maximum radial tooth force due to arm cylinder \( F_S \).

\[
F_S = \frac{p \times \left( \frac{d_A^2}{d_D} \times d_E \right)}{d_F}
\]

Where, \( dF \) is the sum of bucket tip radius (\( dD \)) and the arm link length in mm, and \( dA \) is the end diameter of the arm cylinder in (mm)).

### IV. DESIGN OF JOINT

There are number of forces acting on the joint. Bucket penetration into a material is achieved by the bucket curling force (\( F_B \)) and arm crowd force (\( F_S \)). Considering reaction of these forces are assumed to act on the joint and the vertical forces due to the weight of the arm the joint is design.

![Fig. 2](image)

It consists of shaft which one end is coupled with the motor armature shaft and other end to the arm, two sets of ball bearing and one set of taper roller bearing as shown in the fig 3. In taper roller bearing, the line of action of the resultant reaction makes an angle with the axis of the bearings. This reaction can be resolve into axial and radial component. The bolt is provide to lock the shaft with the bucket arm. The shaft is subjected to various forces torsional, bending, axial, tensile etc. ASME code is used in designing the shaft of the joint.

### V. WORKING OF THE ROTARY JOINT

The shaft is coupled with the motor armature shaft. The power to the motor is provided by the alternator, as the motor rotate the shaft also rotate, the shaft is fixed to the bucket arm by the bolt, and the bearings help in making the rotation smooth. The rotation can be done only in no load condition or without any forces except the weight of the bucket, it can rotate in both the direction clockwise and anti clockwise by reversing the polarity of the motor. The top view of the arm is shown below in fig 3.

![Fig. 3](image)

The maximum power required by the motor

\[
T = r \times F
\]

\[
P = \frac{2\pi NT}{60}
\]

Where \( T \) is torque in N-mm, \( r \) is the displacement vector (a vector from the point from which torque is measured to the point where force is applied), \( P \) is the power of the motor and \( N \) is the rpm. The force acting on the joint during the rotation is mainly the weight of the bucket arm.

Different position of the arm is shown in the fig : 4

![Fig. 4](image)
VI. CONCLUSION

The paper shows that by determining various reaction forces a rotary joint can be designed for the excavator arm, which facilitate the rotation of the arm and increase the productivity. This is very important to analyze all the forces during designing process, selection of material, power of motor. The excavation could be carried out in different position of the bucket(fig-4).

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