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The Simulation Research of the reamer of the cutter suction dredger based on ADAMS

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Abstract: *There are many rivers and lakes in china, In order to prevent floods, the river need to be dredged timely. Cutter suction dredger plays an important role in dredging, the reamer is one of the important devices., Cutting force is more important in the study of the reamer. When design the reamer, due to the complex cutter arm contour lines. It is difficult to analyses the work of the reamer. This paper simulates the movement of the reamer, studies the curve of the F-t and the relationships between the installation angle and cutting force. Then determine the best working angle.*

Keywords: *cutter suction dredger, cutter tooth of the reamer, installation angle, ADAMS*

I. INTRODUCTION

Cutter suction dredger has been widely used in dredging. Cutter suction dredger originated from American, Then spread across the world. Sixties and seventies in the 19th century, Evans carried out the coal cutting experiment. Proposed the cutting force model on the base of the maximum tensile stress. In the 1980s. DELL Ford Science and Technology University began to study the cutting theory of water saturated sand. Professor Ir. G.L.M. do a one to one actual experiment about reamer cutting rock; Dredging research center of Hehai University combine the CAD and CAE software to study the three dimensional model of the dredger reamer; Shanghai Jiao Tong University developed dozens series of large-scale cutter-suction dredger from non-self-propelled to self-propelled and they can dredge high strength rock.

In the working process of the cutter suction dredger, The reamer plays a very important role. This paper mainly studies the installation angle of the cutter tooth, the installation angle directly affect the cutting efficiency and the electrical power needed to drive the reamer work. Studying cutter tooth installation angle have an important significance for the structure and the life of reamer.

II. THE STRUCTURE OF THE REAMER

The reamer is a main component of cutter suction dredger. Its main role is to cut the river's sediment and rocks ,broken them and make the broken sediment, rock and water mixed. Reamer generally consists of a large ring, arm, cutter and hub. The hub and the large ring are connected to a whole by a plurality of arms, The hub is connected with the shaft, it is used to transmit force and torque. Cutter tooth are installed on the arm of the reamer, which is the function of cutting. The arm contour line and the installation angle of the cutter tooth directly decide the cutting performance of the reamer. Fig 1 is structure diagram of the reamer.

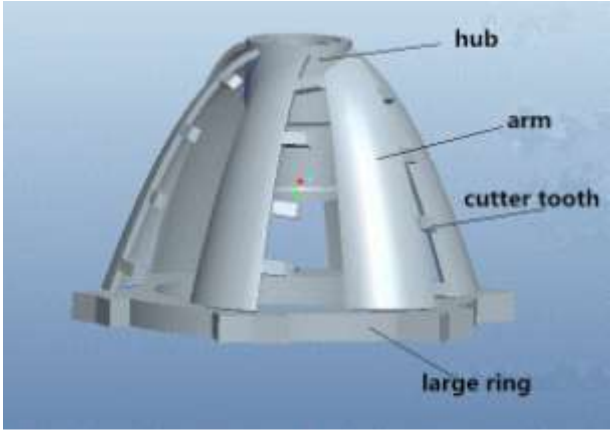


Fig.1 Structure of the reamer.

III. THE WORKING PRINCIPLE AND THE INSTALLATION ANGLE

3.1 THE WORKING PRINCIPLE OF THE REAMER

When working, there are two kinds of the main movement, one is rotating itself, the other is translational motion, So the movement of the cutter tooth is synthesis movement of the translational motion and the rotary motion. According to the direction of these two movements, the reamer cutting can be divided into positive cutting and anti cutting. When the direction of the cutter tooth tips movement as same as the translation movement, it is anti cutting. The opposite is positive cutting[6]. Anti cutting is generally used, Because of the relatively high cutting quantity, it can make the clay particles come to the suction mouth under the action of the arm.

(a) Positive cutting (b) Anti cutting

Fig.2 Movement of the reamer.

When cutting, the cutter tooth is affected by the two movements at the same time. In order to analyze the movement of reamer, the three-dimensional model of reamer is simplified to two-dimensional flat. In the two-dimensional flat cutting. Cutter tooth tip movement is a synthesis movement of translation movement and rotational movement. The trajectory of cutter tooth tip as shown in Fig 3.

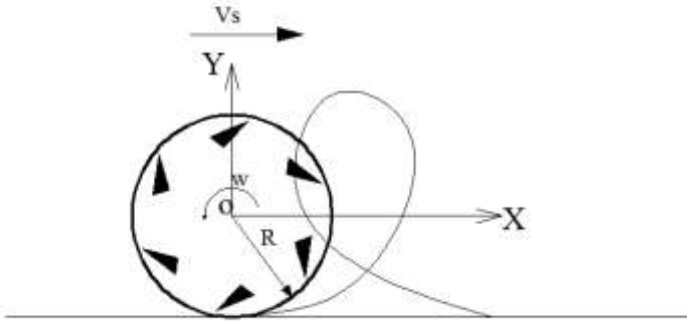


Fig.3 The trajectory of cutter tooth tip

Establish coordinates to the movement model, set the reamer axis as the coordinate center, Translational direction as X axis, The rotation direction counterclockwise around the center of the reamer, Study on the cross section of the radius of R， Suppose reamer translational velocity is Vc, spinning speed is w, the time is t, The parametric equation of the trajectory of the cutter tooth tip is as follows:

$$\begin{cases} X = Vst + R\sin wt \\ Y = R\cos wt \end{cases} \quad (1)$$

According to the trajectory of the cutter tooth tip, The speed of the horizontal direction is Vx, the speed of the vertical direction is Vy, Derivative both sides of equation (1) to get the velocity parameter equation (2).

$$\begin{cases} Vy = -Rw\sin wt \\ Vx = Vs + Rw\cos wt \end{cases} \quad (2)$$

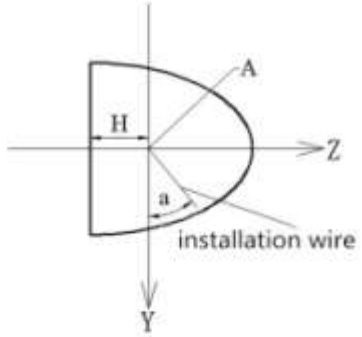
The velocity of the cutter tooth tip can be obtained by the equation (3).

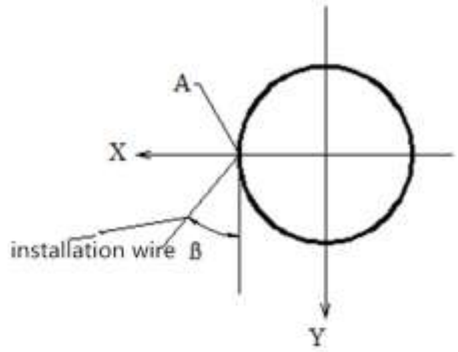
$$V = \sqrt{Vx^2 + Vy^2} = \sqrt{R^2 w^2 + Vs^2 + 2VsRw\cos wt} \quad (3)$$

When the reamer moves in a certain angular velocity, the speed is cyclical change, it can be seen from the fig(3). The cycle $T = 2\pi / w$, In a quarter cycle, the speed of the cutter tooth will reach the maximum.

3.2 CUTTER TOOTH INSTALLATION ANGLE

Since the projection of the reamer installation wire in the two vertical coordinate plane is only, the installation angle of the cutting tooth can be determined by the angle between the installation wire and the coordinate plane. Define the plane which perpendicular to cutter axis as the X-Y plane, define the plane which pass through the cutter axis and perpendicular to the X-Y plane as the Y-Z plane. Analyze the installation point A which on the outer contour take from the big ring H. Set the angle between the projection of the installation wire and the Y-axis as α in the Y-Z plane. Set the angle between the projection of the installation wire and the Y-axis as β in the X-Y plane. The cutter tooth installation coordinate system as shown in fig 4.





(a) Y-Z Plane (b) X-Y Plane

Fig.4 The installation coordinate system of the reamer

The installation angle determined by the angle between the installation wire and each coordinate plane. Set the angle between the installation wire and X-Y plane as θ1, set the angle between the installation wire and the Y-Z plane as θ2, set the angle between the installation wire and the X-Z plane as θ3, the installation wire in the spatial coordinate system as shown in Fig 5, according to the geometric relationship betweenθ1, θ2 and θ3, get the expression of the θ1, θ2 and θ3 .

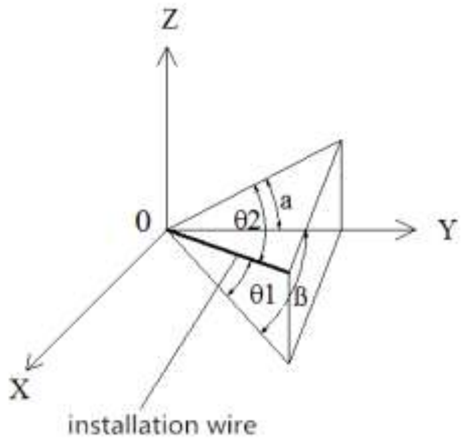


Fig.5 Projection of the installation wire

$$\begin{cases} \tan\theta 1 = \tan\alpha * \cos\beta \\ \tan\theta 2 = \tan\beta * \cos\alpha \\ (\tan\theta 3)^2 + (\tan\alpha)^2 + (\tan\beta)^2 = 1 \end{cases} \quad (4)$$

When α, β is determined, the installation angleθ1, θ2 and θ3 is determined. Study the relationship between the installation angle and the cutting force. This has an important significance in production and research of reamer.

IV. SIMULATION OF THE CUTTER TOOTH

The installation angle of the cutter tooth can be determined by theθ1, θ2 and θ3, Different installation angle produce different cutting force and need different power of motor. Reamer main movement is rotating and translational, the movement of cutter tooth is the synthesis of translational motion and rotation movement. Reamer rotating speed is usually 10 to 50 r/min, select 30r / min to simulate; Reamer translational speed is 0-0.5m / s, select 0.2m/s to simulate; Because the cutter tooth tip is the most easily damaged, so the research on the cutting force is the cutter tooth tip. Use ADMAS to simulate cutter tooth movement. Study the influence of installation angle and the cutting force and motor power. Movement model is set up as shown in fig 6.

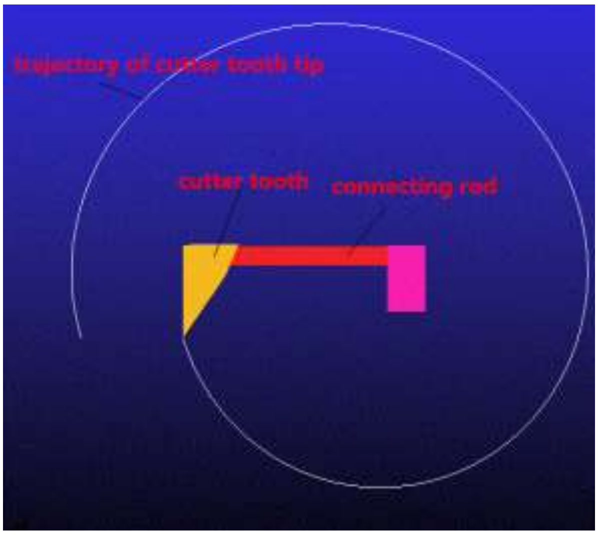
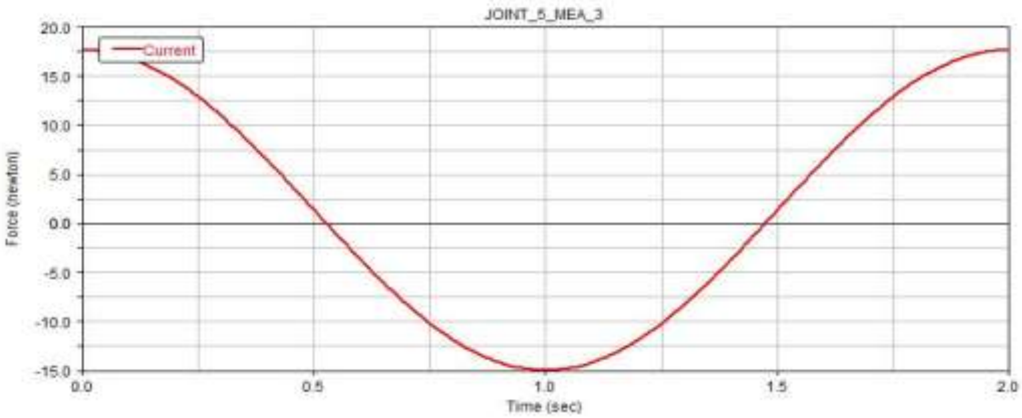


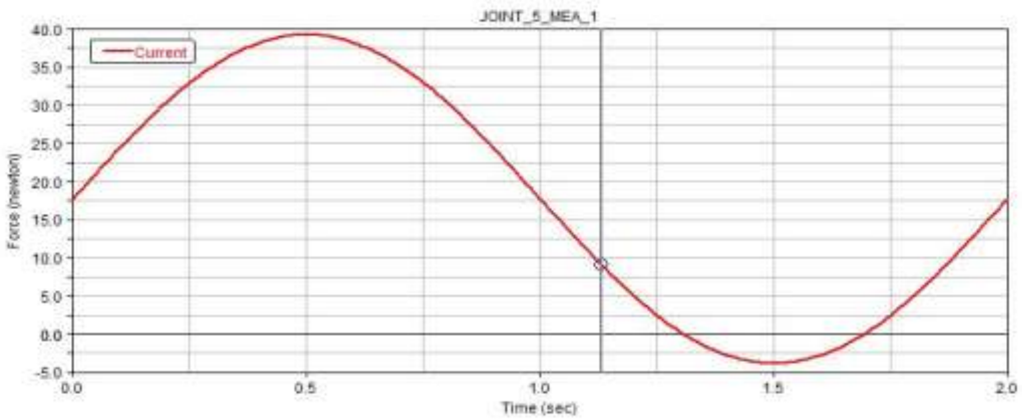
Fig .6 Simulation model of the cutter tooth and trajectory of cutter tooth tip

4.1 SIMULATION OF THE CUTTING ANGLE IN THE X-Y PLANE

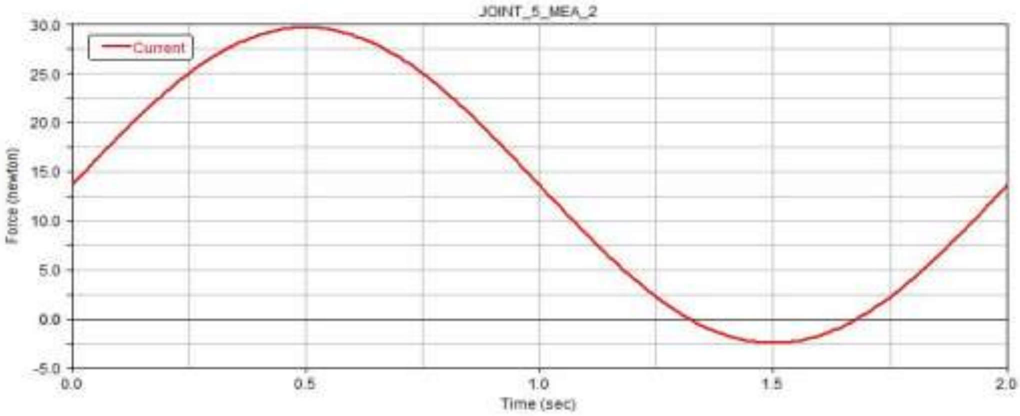
In the X-Y plane, vary the angle between the installation wire and the Y-axis, select 0 °, 30 °, 60 °, 90 ° to simulation. Get the F-t curves and torque curves. Compare these four F-t curves, the curve as shown in fig7.



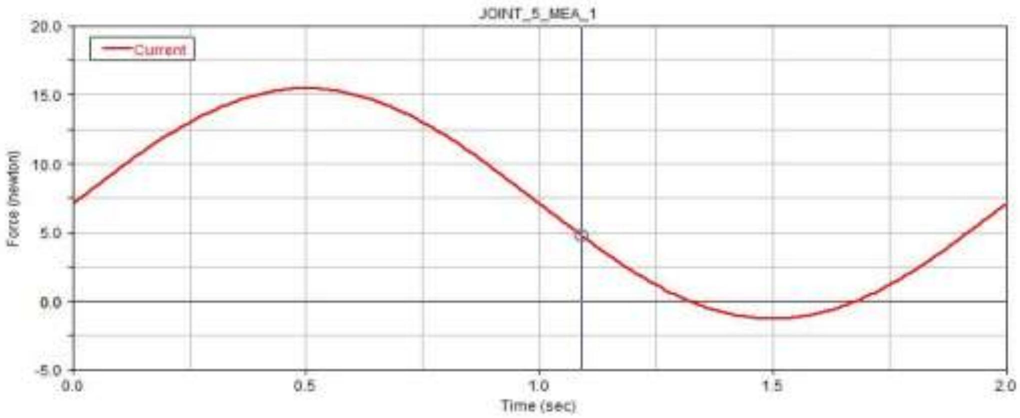
(a) Simulation results for 0 °



(b) Simulation results for 30 °



(c) Simulation results for 60 °



(d) Simulation results for 90 °

Fig.7 F-t curves of different angles

Study the movement simulation in the X-Y plane, it is found that cutting force of the cutter tooth is changed with time. In 0.5 seconds, when the cutter tooth move to the bottom, the cutting force reach maximum. The maximum cutting force and the maximum torque in these four cases as shown in table 1. From table 1, it is found that the maximum torque increases with the increase of angle, As the angle increasing, the maximum cutting force increased first and then decreased. In 30 °, the cutting force is maximum. The maximum cutting force increase faster from 0 °to 30 °. Under the same operating conditions, the installation angle in the X-Y plane should be selected to around 30º to produce a relatively large cutting force.

Table .1 The maximum cutting force and torque of the different angles

Angle(°)	Maximum torque (N/m)	Maximum cutting force (N)
0	175.0	17.6746
30	180.14	39.2658
60	183.2	29.6886
90	183.45	15.4622

4.2 Simulation of the cutting angle in the Z-Y plane

In order to determine the cutter tooth installation Angle, it is need to determine the installation angle on the

Z-Y plane. In order to study the installation angle on the Z-Y plane, it is necessary to maintain the installation angle on the X-Y plane, and change the installation angle of the cutter teeth in the Z-Y plane.

Simulation model as shown in fig 4, Keep the installation angle on the X-Y plane is invariant to 30°, change the installation angle from 0 ° to 60 ° on the Z-Y plane, The simulation results are shown in Table 2.

Table.2 The maximum cutting force and torque of the different angles

Angle(º)	Maximum torque (N/m)	Maximum cutting force (N)
0	180.14	39.2658
30	180.02	76.7445
60	179.96	37.746

It can be seen that the maximum torque reduce with the increase of the angle on the Z-Y plane, When the angle increases to 30 °, the cutting force is the maximum. The cutting force is larger, the cutting is better, the torque is greater, the required motor power is greater. In the case of the motor is selected, the installation angle should be selected around 30º on the Z-Y plane.

V. CONCLUSION

Use ADMAS to simulate the cutter tooth in different installation angle, study the relationship between the installation angle and cutting force, get a reasonable installation angle. When the installation angle is around 30 º, the cutting is better, It has guidance meaning to the design and installation of the reamer.

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