CSCanada
Advances in Natural Science
Vol. 8, No. 1, 2015, pp. 27-32
DOI:10.3968/6128

ISSN 1715-7862 [PRINT]
ISSN 1715-7870 [ONLINE]
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Investigation on Fitting Method of Snail Structural Lines

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Received 14 November 2014; accepted 19 February 2015
Published online 26 March 2015

Abstract

For the current status of the spudcan design and combining the characteristics of bionics, on the basis of shells on the solid model, the paper study the spiral geometry characteristics and distribution. Regarding the shape of the surface characteristics of the spiral portion and snail shells spiral suture lines, a feature reverse scan statistics can be made. Snail shells overall shape evaluation can be established and micro-element methods are used to deduce the 2D mathematical expression so as to provide a good reference for the design of jack-up platform spudcan.

Key words: Bionics coupling; Spiral; Micro-element method; Spudcan

Tang, W. X., Wu, W. L., Gao, Z., & Li, J. T (2015). Investigation on Fitting Method of Snail Structural Lines. *Advances in Natural Science*, *8*(1), 27-32. Available from: http://www.cscanada.net/index.php/ans/article/view/6128
DOI: http://dx.doi.org/10.3968/6128

INTRODUCTION

The bionics study structure, properties, principles, behavior and interaction of biological systems. It provides some new design ideas for engineering, working principle and system structure. The biomimetic material means that a material can be made based on bionics, bio-mimic various features and characteristics. And the design of material biomimetic material has three aspects includes material bionic structure, function, and system. Thus, the paper chooses the snail shell to research its properties (Lu & Jiang, 2010; Cen & Chen, 2007; Gao, 2008).

Snails are widely distributed in lakes, streams, ponds, marshes, paddy fields and small ditches and other places. In the cold winter, they do not eat and move after they drill to the soil. Until the arrival of spring period, they crawl out from the soil. We can find that their shells shape is always similar. The snails grow from the top of shell along shells mouth. This growth pattern is not only able to maintain the same basic shape of shells and shell quality does not waste too much to get enough memory space (Tian, 2013). Many snail properties are associated with his helix. Why the spiral widespread in living organisms? Animals in water snails usually carry with a heavy shell to crawl. The larger diameter portion is in front of shell, and the small diameter portion is at the rear. When advancing against the current, the rotational flow along the large diameter portion of the shells to a small diameter portion, then the flow rate will be greatly reduced, so that the rear end of the shells located in hydrostatic pressure will be greater than the hydrostatic pressure of the front end. Shells will automatically move forward depend on pressure difference from the front and rear. In addition, the distribution of snail shapes like a spiral rib, effectively enhance the strength of shells and decent water pressure. Visibly, in order to adapt to the complex living environment, shells evolved excellent biological function with high strength, large space, reducing viscosity and desorption properties, which can provide a good reference for the design of spudcan (Gao et al., 2007).

1. THE DESIGNED SITUATION OF JACK-UP PLATFORM SPUDCAN

In order to meet the increasing energy demand, oil exploitation was gradually transferred from the landward area to the offshore area, even to the deep sea. China boasts a mainland coastline of more than 18,000 km, and the islands' coastlines total more than 14,200 km (Li, 2008). China is very rich in oil and gas resources. Jack-up platforms are the indispensable equipment for offshore oil and gas exploration, which includes hull, lifting mechanism, platform leg, platform spudcan. Currently, the working depth of jack-up platforms is becoming to be designed deeper, even more than 100 meters (the working depth reached 168 meters abroad). With the working depth increased, the condition of (Dong, 2007). In September 2012, the State Council issued the notice of the development of national marine economy in the "Twelfth Five-Year Plan", in the oil and gas exploration and development equipment field, we should focus on the development of jack-up platform, master the technology of independent design and construct oil and gas Exploration equipment in Figure1.

Figure 1
The Typical Platform Spudcan

The requirements of the design of jack-up platform spudcan are as follows insert into the soil breezily, stand steadly, pull out easily. In the condition of inserting, the size and the shape of the spudcan affect the inserting depth, which determines the overall length of spudcans. A good design of spudcan should avoid Punch-through failure to ensure the safety of inserting and standing. In the condition of standing, the size and the shape of the spudcan determine the stiffness connection between the spudcan and soil, which affect the dynamic response of jack-up platform. Enough vertical bearing capacity and lateral bearing capacity is the protection to avoid the occurrence of piercing and slip accident. In the condition of pulling, the size and the surface shape of the spudcan determine the adhesion properties betweed the spudcan and soil, which affect the load of pulling and the structure strength of jack-up platform. With the platform working depth and the overall weight increasing,standing and pulling piles should have more higher performance requirements (Xie et al., 2013). In order to make sure the safety, the design requirements of jack-up platform spudcan become higher. Therefore, to carry out the research on the design theory and methods of jack-up platform spudcan has an important significancein in improving the safety of offshore oil and gas exploration, reducing the incidence of malignant accidents, avoiding casualties or damage to equipment and security oil and gas energy supply of our country.

Most of the designs of jack-up platform spudcans are based on the experience of trial and error, as we do not have mature theory. There are three kinds of its shape including cylindrical, conical and rotational hyperboloid. The horizontal conical shape between 120-150 degrees is the mainstream, and the equivalent diameter is between 10-20 m (Wu, 2013). It is composted of crisscrossing steel or welded steel. More over, most of the surfaces are smooth. However, there are common problems in these spudcan designs:

(a) In order to meet the requirements of strength and stiffness.On the one hand, as the the large amount of steel, it is difficult to increase the size, which results in the stress of soil became large and increased the probability of pierce in the condition of inserting and standing; On the other hand, as the high-density of steel, the available space is not continuous and small, which make the equipment layout difficult.

(b) However the taper of the platform spudcan is huge while the projection area is small. The bearing capacity of horizontal direction is not high enough, which will affect the positioning capability in the condition of inserting as well as the anti-slip capability in the condition of standing.

(c) The connected stiffness between spudcan and soil is very small, leading to the oscillation frequency of jack up platform reduced and the maximum stress of the spudcan which is gradually increasing transferred to the fixed frame area. What's more, due to the deterioration of the dynamic response characteristics, the design of jack-up platform spudcans puts forward higher.

(d) As the outer surface structure of the spudcan is smooth and the adhesion force between the spudcan and the seabed soil is very large,it is difficult to pull. What is more, it will cause the platform stress increases and affect the pulling efficiency as well as the structure strength of the jack-up platform (Guo et al., 2012).

As there is little research on snail, if we can apply the features of snail such as high strength, large space, anti adhesion properties to the jack-up platform spudcans, this will provide great convenience for the design of the jack-up platform.

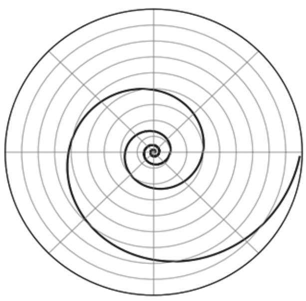
2. THE RESEARCH STATUS OF MECHANICAL BIONIC COUPLING

In 1960, national aeronautics and space administration（NASA）held its first international conference about bionics and bionics truly emerges as an independent discipline. In 2006 and 2008, China successfully held the session of the International Conference on bionic engineering, which signs that bionics becomes a hot research in our country (Qian et al., 2008). In recent years, a large number of studies on bionics have shown that the surface of soil animal body, the plant surface with "lotus effect" and the surface of aquatic animals have the ability of Anti-adhesion, anti-resistance and drag reduction. The research of biological non-smooth surfaces which include structural analysis, material bionics and function bionics, focus on the typical biological in a certain environment. The research by studying the surface morphology, microstructure, the composition of surface material and the state of motion, gains superior performance bionic products which meet the actual needs.

Academicians in Jilin university raised the concept of biological coupling firstly (Ren et al., 2005), which noticed that in order to adapt to the living environment, the organism showed various functions. That is the coupling result by the number of biological surface morphology, surface structure and material interdependence. These factors are mutual affected and interdependence (Xia et al., 2014). Their teams carry out the systemic research around a variety of biological coupling characteristics. In the field of mechanical bionic coupling design principle and key technology, they made a great contribution. Many professionals systematic study its biological characteristics, mechanical properties and wear properties by the characteristics of the shellfish, typical clam, conch and chitons vein. So they reveal the wear-resisting characteristics and rules of shellfish biology. They also research the bionic slats and bionic multistage airfoil rising role in the long-eared owl wings. According to the aquatic organisms and the characteristics of dynamic changes in surface, they raise bionic coupling function of active control the fluid and realize the function of synergistic drag reduction. Based on these researches, it provides the methods for us to solve security issues of the jack up platform spudcan.

3. GENERAL EXPRESSION OF THE LOGARITHMIC SPIRAL

In nature，there are numerous of spiral forms, such as the surface of the sunflower, tornado vortex, the structure line of snail shell, even genetic organisms are spiral forms. The general helix equation mainly includes Archimedes spiral, logarithmic spiral and exponential helix spiral paper choose the logarithmic spiral to fit the (Gao et al., 2007). Because the logarithmic spiral and snail shape are closer (Yan, 2013) (Figure 2), the curve obtained from scan model.



(a) Standard Logarithmic Spiral

(b) Snail Logarithmic Spiral

Figure 2
Logarithmic Spiral

3.1 Characteristics

With respect to the arm distance of the logarithmic spiral, the distance increases geometrically. The straight line L is an arbitrary straight line passing through the origin, then the angle between L and logarithmic spiral is always equal. Logarithmic spiral is self-similar. That is to say, the enlarged image is exactly as same as the original one (Pu, 2011; Fruhwirth & Strandlie, 2002; Stefanell, & Rosenfeld, 1971; Sui et al., 2014).

3.2 Logarithmic Spiral Expressions

In Figure. 3, firstly using the micro-element method, the $\partial\theta$ will infinitely close to zero. The line u infinitely closes to zero and the arc length of u equal to the length of s. We can get the expression (1).

$$\cot\varphi = \frac{\partial r}{\mathrm{d}s}. \tag{1}$$

Secondly, according to the classic formula of length: $s=r \cdot \theta$, the derivation formula was carried out on both sides:

$$\partial s = r\partial\theta . \tag{2}$$

Bringing the Equation (2) into Equation (1). After integrating both sides at the same time:

$$\ln r = b\cdot\theta + c. \tag{3}$$

Where $b = \cot\varphi$, φ is constant.

Finally, the logarithmic spiral mathematical expressions are:

$$r = a\cdot e^{b\cdot\theta} . \tag{4}$$

Where $a=e^c$, c is constant.

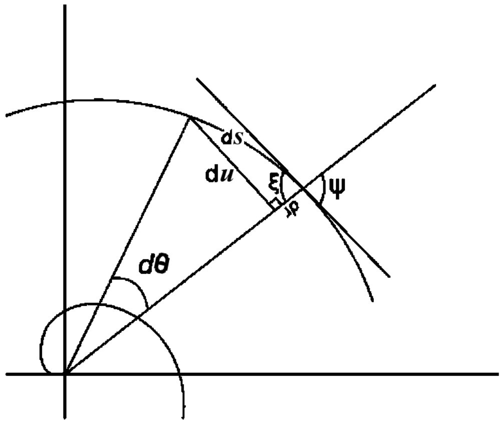


Figure 3
Spiral Parameters

4. FITTING THE LOGARITHMIC SPIRAL

Known to the expression of logarithmic spiral, we can fit the Snail sutures. Based on the five nearly identical appearance snail reverse scan, we draw a 3D model of snails. Because the scanning pattern exists defects, the models are introduced into HYPERMESH software to fetch suture points. Each point coordinates values can be obtained, as shown in Figure 4.

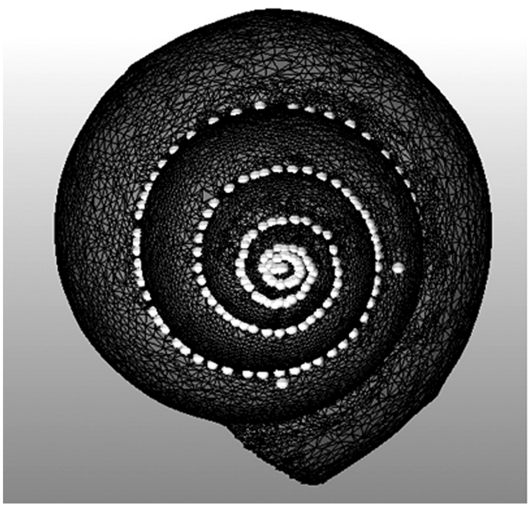


Figure 4
Hypermesh Taking Dot Plot

From the graph image, the shape of logarithmic spiral is not a conventional straight line. It is difficult to fit the curve directly. So this expression of the equation by interchanging both sides at the same time taking the logarithm:

$$\ln r = b \cdot \theta + \ln a. \tag{5}$$

Obviously, Equation (5) is a linear equation and fitting them are more convenient. The result can be seen as a type of linear equations between ln r and θ, so that it can be fitted through the origin software to get the equation of the line (Li , Chen, & Zhang, 2010). Then the coefficient b and a can be calculated in the equation. As equivalent changing, all data points are also affected, which makes all the data can not be simply brought into expression. Establish a relationship about ln r with (x, y) values by geometric relationships, which make Cartesian coordinate system transform to the coordinates (θ, ln r).

Because it can not come to the real image of the curve, only approximate spiral line through the infinite points. The article will begin to get the point with AUTOCAD by polylines in the approximate 0~2π range of the image, and then every θ angle (θ=12°) in the thread line can take the point and eventually get about 31 points, as shown in Figure 5.

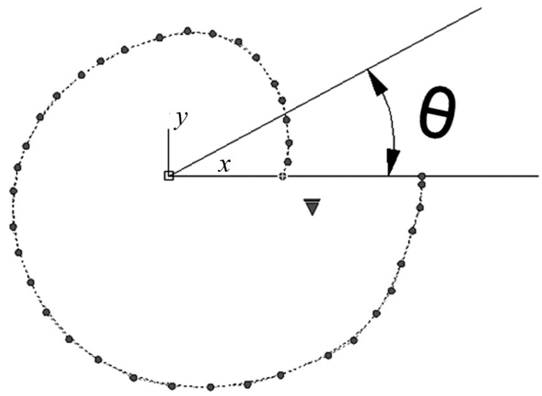


Figure 5
Scatter Diagram Spiral

Equation is the relationship about θ with lnr, so all the polar radius r is converted to logarithmic form. In order to facilitate the calculation, let P_i=lnr_i, then we can get:

$$P = b \cdot \theta = \ln a. \tag{6}$$

It can provide a great convenience for later linear fitting. This image can be fit through the origin software, then obtain the value of ln$a$ and b, in Figure 6.

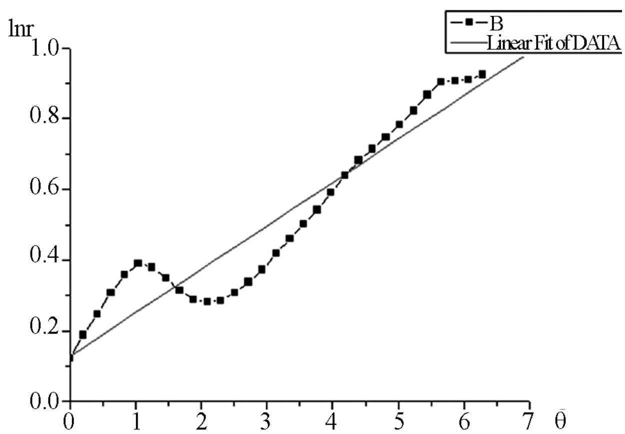


Figure 6
The Image Between ln$r$ and θ

4.1 Expression With Constant Parameters

Clearly, all the points are located at both ends of the line and the values of lnaand b may also be obtained directly:

$$\begin{aligned} \ln a &= 0.13, \\ b &= 0.12. \end{aligned} \tag{7}$$

To arrive at a = 1.4, b = 0.12, snail preliminary sutures can be fitted for mathematical form:

$$r=1.4e^{0.12\theta} \tag{8}$$

4.2 Expression With Modified Parameters

According to Figure 6, spiral inevitable exists errors, such that the true values of a and b have greater access. In the case of different angles may have a corresponding fluctuation, the helix wants to the greatest extent to meet the requirements of this paper on the establishment of a, b and θ function formula to reduce fluctuations in error. Similarly, we can draw each value of a and b through the micro-element method and ignore the flaws point. Then we can fit the curve through the origin software, which summed up the relationship, in Figure 7.

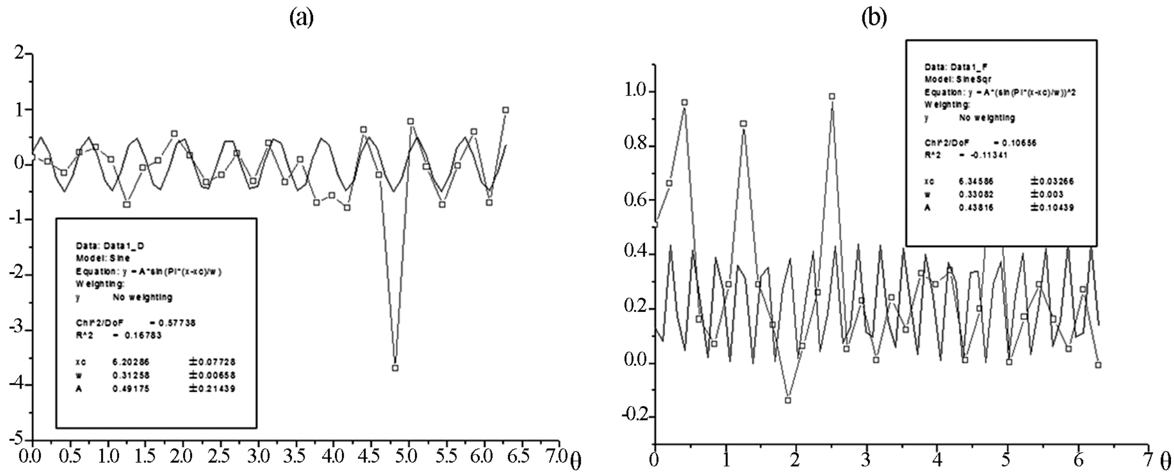


Figure 7
Expression Parameter Diagram

From the above figure can be obtained respectively:

$$\ln a = 0.49 \cdot \sin\left(\pi \cdot \frac{\theta - 6.2}{0.31}\right), \tag{9}$$

$$b = 0.44 \cdot \left[\sin\left(\pi \cdot \frac{\theta - 6.35}{0.33}\right)\right]^2. \tag{10}$$

Replace these two expressions into the expression (8) , the result expression is:

$$r = e^{0.49 \cdot \sin\left(\pi \cdot \frac{\theta - 6.2}{0.31}\right)} \cdot e^{0.44\left[\sin\left(\pi \cdot \frac{\theta - 6.35}{0.33}\right)\right]^2 \cdot \theta}. \tag{11}$$

5. VERIFICATION OF THE EXPRESSION

The logarithmic spiral equation can be rendered by MATLAB software, in Figure 8. The images show a serrated spiral, but it is poor in the image of the logarithmic spiral. The constant is converted to a function unreasonably. However, we use the original expression (8) to compare with the original image. It will be prepared with a logarithmic spiral equation through CAXA software rendering with the original coordinates plotted, as shown in Figure 9.

The black line represents the expression of the fitting out of the spiral curve, red represents the original coordinate points plotted curve. Obviously, the expression is more close to the actual. The fitting process is carried out in 0~2π range of values, but the fitting out of the image applied to any angle. Thus, the expression (8) is the best expression.

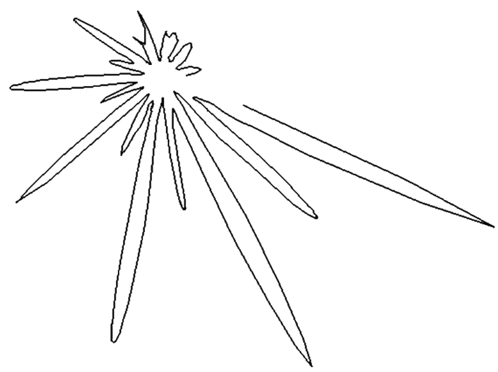


Figure 8
MATLAB Fitting Graphs

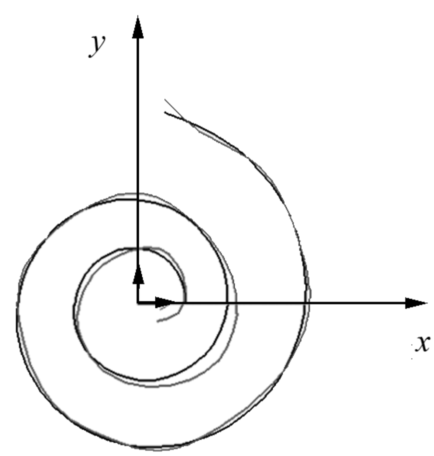


Figure 9
Helix Comparison Chart

CONCLUSION

In this paper, for the current status of the spudcan design and combining the characteristics of bionics, by analyzing the problems existing in the real shoe and mechanical bionic coupling study of the status situation, it can provide the design of the platform spudcan with the characteristics of shells large space, high strength and viscosity reduced. The solid model scans can be obtained and take the value at the surface. Based on the logarithmic spiral of the expression deduced, then the snail surface characteristics can be transformed into a mathematical model. We can find that the result mathematical expressions are in good agreement with the original model. It can better reflect the true shape of snail sutures and achieve the desired effect. This is better for the future research of snail itself and provides a mathematical basis. At the same time, it also lays the foundation for the design of the jack up platform spudcan.

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