

Prionace Glauca Streamline Body 3D Printing Technology Research and Application

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Abstract. Prionace glauca can cruise long distance with high efficiency. The study on hydrodynamic characteristics of *prionace glauca* streamline body three-dimensional(3D) model will provide important reference value for the optimization design of autonomous underwater vehicle (AUV) and other marine equipment. 3D model is established based on the description of the *prionace glauca* specimen numerical value and biodegradable plastics PLA is chosen as 3D printing materials. According to model data that has been generated by the computer, the *prionace glauca* 3D model is produced with increasing material technology and the water resistance test is conducted. The experiment results show that 3D printing technology has greatly shortened the development cycle of product, improved productivity and reduced production cost compared with the traditional manufacturing method. In addition, the 3D model provides a powerful proof for mechanical properties verification of prionace glauca in the flow and lays the foundation for AUV structure optimization design and other related applications.

Guidelines

The traditional manufacturing technology can be taken as "reducing the material" with long production cycle, high rejection rate and high cost. Special shape parts are usually produced by cutting, grinding, etching and melting, and then the parts are assembled through welding and other methods. Under this background, 3D printing rapid prototyping technology was gradually developing[1-2]. 3D printing is different from the "reducing materials manufacturing" of the traditional manufacturing industry, it belongs to the "additive manufacturing", but without any moulds or mechanical processing, it can be directly controlled by the computer model datas that have been generated, and it also produces the required objects by increasing material technology. Thus the application of 3D printing, which greatly shortens the product development cycle, improves productivity and reduces production costs, it is suitable for the efficient processing of conventional complex body, too[3]. 3D printing technology has connected the production process, technology, equipment, materials and applications in the "rapid prototyping" and "rapid manufacturing".

3D printing technology, as a new material processing and molding technology, will change the way to make all products and has become one of the most important symbols in the third industrial revolution[4]. 3D printing, originated from the end of 1970s to the beginning of 1980s, has played an important role for the increasing material manufacturing technology. That is, manufacturing parts prototype by the method of superimposing directly layer by layer. 3D program is designed mainly by the computer software and the 3D ink-jet printing equipment, which needs powder, filaments of liquefaction and other special materials, it prints layer by layer through the combination of stratified processing and superposition forming method, and reach the destination so that 3D printing is in the same level with laser forming and other 3D model manufacturing technology of the digital manufacturing technology in the real object. The key technical advantage is to make complex structure products with different materials by using digital means of rapid manufacturing[5]. It can be applied to saving energy and material in some sophisticated process of advanced manufacturing fields. Nowadays, 3D printing technology is widely used in military,

medical, biological and other fields, In the Poland Pierwszych Museum, there are a number of very colorful and realistic 3D printing fish models, which has aroused widespread attention. As shown in Figure 1. These fish models are created by using 3D printing technology, they resemble the real fish both in size and shape, and become more realistic after the late color treatment.



Fig.1 3D printing fish model

The prionace glauca has high efficiency and long-distance cruising mode, the pectoral fin of which plays an important role in the balance and stability and the head of which is the main source of resistance. It is greatly valuable for the optimization design of AUV and it is also a great breakthrough that other marine equipment that the head and pectoral fin is used to research. In order to realize the description of the prionace glauca form numerical value, obtain the force distribution of head and pectoral fin of prionace glauca, we use 3D printing technology to print out the prionace glauca 3D model, and then test the model to obtain the relevant data. The result of this process will help to verify the correctness of the theoretical study of the prionace glauca model. Prionace glauca 3D printing mainly uses the bonded materials, such as ABS or PLA. It builds a three-dimensional model of the "partition" layer section by computer aided design (CAD) or computer animation modeling software modeling, to guide the printer printing layer.

Analysis of 3D Printing Technology

3D printing material is the basis of 3D printing. At the present, 3D printing materials mainly include metal materials, ceramic materials, polymer and composite material, in which ABS and polylactide (PLA) plastic are mainly used. ABS with a stable printing process, high strength and toughness of products is the first application in the FDM printing of polymer materials. It also has a good hot melt and easy extrusion. But ABS's material shrinkage rate is high, which limits its application so that it leads to shrinkage deformation of the product with an ease and becomes prone to delaminating and warping. At the same time, the process will result in decomposition of part of the material and producing odor as well as wasting energy when the printing temperature of ABS is up to 230°C. PLA is a kind of environmental-friendly biodegradable thermoplastic plastic, the final degradation products of which are carbon dioxide and water. PLA has excellent mechanical properties, thermal plastic, fiber, transparency, biodegradability and biocompatibility, and is widely used as FDM printing supplies, especially in the field of biomaterials[6-7].



Fig. 2 prionace glauca

Prionace glauca is a typical-large marine organism, its shape can be divided into four parts: head, pectoral, trunk and tail, as shown in Figure 2. The overall shape is complex. Characteristics are shaped more precisely and achieve the simulation results. It needs to build 3D modeling refer to the actual size of the prionace glauca specimen. According to a survey of prionace glauca specimens, the length of the fish body is 2131.0mm, fork length is 1910.5mm, width is 1102.2mm, the fish tail length is 410.0mm, the maximum height of prionace glauca is 558.5mm, pectoral fin length is 440.6mm, the maximum width of pectoral fin is 190.5mm, and the horizontal angle is 5 degrees. To show the multi shape model of prionace glauca, we construct linear and wagging model of prionace glauca under natural conditions according to the size of the prionace glauca, as shown in Figure 3.

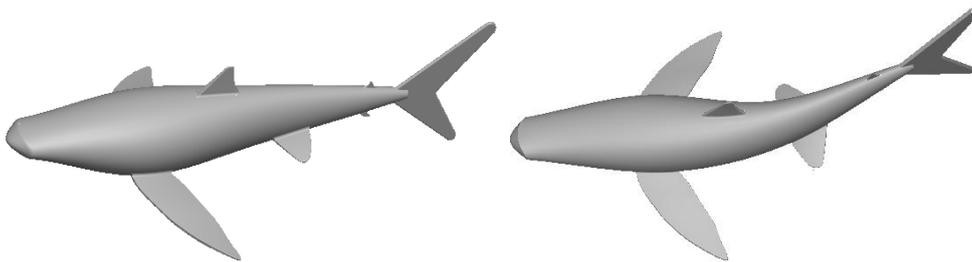


Fig. 3 prionace glauca model

In view of requirements of the size of the model of 3D printer, it needs printing 3D model for scale. Now the size of prionace glauca specimen is in accordance with the proportion of zoom 4:1, we import the model from slicing software and deal with it through section processing, and set wall thickness of the model, in the way of layered hollow printing. In order to control the balance with the ups and downs of the model in water, it can be accomplished by adjusting weight center of prionace glauca model.

Realization of 3D Printing Process

3D printing steps. (1) Create a model: create a prionace glauca 3D model by the use of three-dimensional mapping software, and store the model document as a unique format. Divide the whole model into several sections according the practical requirement.

(2) Prepare files: the system software will be processed on the 3D model, and the document is converted to the 3D model and the print instructions of the support structure to guide the operation of the printer head.

(3) Print 3D model: make 3D model and support materials layer by layer from bottom to top through making molding technology in the demolition of the molding seat.

(4) Remove the support material: according to their needs, take out a good print model from the

printer's print bin, and then dissolve support material from the molding base, so that the model can be pulled out of use or dealt with in subsequent processing. Connect the divided parts into a whole prionace glauca product.

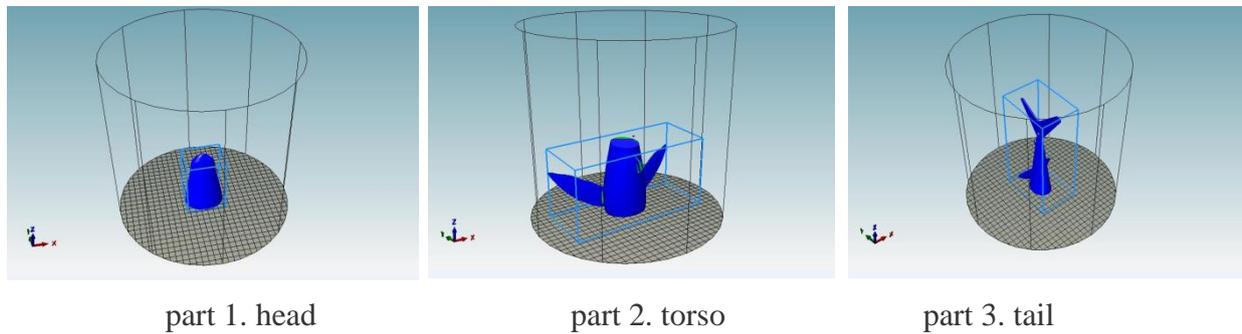


Fig. 4 slices of prionace glauca 3D model

3D printing process of prionace glauca model. First of all, import the contour information of the prionace glauca body model by 3D drawing software in the 3D control software of 3D printer based on the working principle of fused deposition manufacturing technology. And then carry on section processing to generate the corresponding data. The whole body is divided into three parts-head, torso, tail, as shown in Figure 4. It generates relative motion coordinate path, which consists of material and the nozzle after the analysis. According to the program of the bearing in the printing plane, thermal spray will move with plane coordinate displacement under the control of the computer program. And meanwhile, thermoplastic liquid or solid material will be sent to the common hot nozzle through the power operation of the system and the storage mechanism, and then will be heated and be melted into a liquid material through thermal spray after squeezing out the corresponding XY coordinate in the setting of the work platform[8]. Secondly, the spraying thermoplastic materials will form a layer thickness of 3D printing section about 0.1 mm in the plane after rapid cooling. In this circular process, the height of the carrying table will continue to change the displacement, multilayer 3D printing section will form a multilayer stack, and then form 3D multi plane physical model eventually to assemble the three parts of the body completely, as shown in Figure 5. To reduce the deviation of smooth between fish model and natural fish, the fish printing should bring into consistence with 3D model by dealing with the fish body surface with the way of micro correction.



Fig.5 3D printing model of prionace glauca

The resolution can achieve 600dpi at this stage. With the improvement of the precision of printing, the quality will be greatly enhanced. In addition, it is not difficult to exhibit not only the design of shape curve but also the structure and the moving parts. If it is used to print machine assembly drawings, gear, bearing and the rod can be used normally. The accurate position of the groove cavity and the morphological characteristics will meet the requirements of assembly. The entity can also be processed by grinding, drilling and electroplating. At the same time, the powder material is not limited to sand profile material and also includes the flexible, high performance

composite, investment casting and other available materials.

Underwater Resistance Test

The prionace glauca has high efficiency and long-distance cruising mode, the pectoral fin plays an important role in the balance and stability, the head is the main source of resistance. It has great value for the optimization design of AUV and other marine equipment that the head and pectoral fin is used to research as a breakthrough. It is quite difficult to get the performance data of head and pectoral fin of the living experimental subject. At present, the way of obtaining these datas mainly includes fluid simulation software and theoretical analysis of the virtual model, but there is a lack of the experimental verification. In order to provide verification for the fluid numerical analysis, it makes flume experiments by means of the prionace glauca 3D printing simulation model, as shown in Figure 6. The state of the experiment as follows.

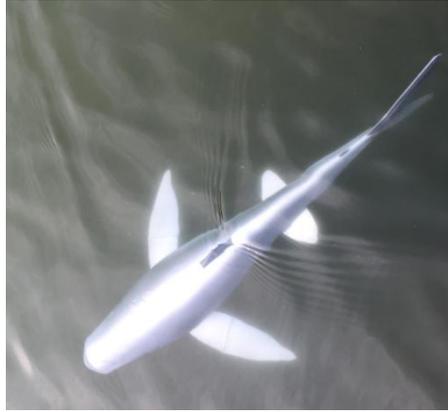


Fig. 6 underwater resistance test

This experiment is finished in the sink where there is a steady flow. In order to maintain the model in suspension in the sink, the prionace glauca model should increase weight of internal adjustment to keep balance before the experiment. In order to study the effect of different flow velocity on the result of resistance and ensure the accuracy of the experiment, the resistance test should be done in 3 states, and each state should repeat 3 times. The flow velocity was 0.54 m/s, 1.12 m/s, 1.51 m/s.

According to CB/Z 216-2008 "Test method of resistance and self-propulsion of submarine model"[9], test data can be dealt with to get the total drag coefficient and friction coefficient under different Reynolds number model, and then obtain the form drag coefficient. The Reynolds number Rn can be determined by the formula as follows.

$$Rn = V \times L / \nu \quad (1)$$

Total drag coefficient C_M is calculated by the formula, as follows.

$$C_M = R_M / (0.5 \times \rho \times V^2 \times S) \quad (2)$$

The coefficient of frictional resistance C_f is calculated by ITTC formula:

$$C_f = 0.075 / (\log_{10} Rn - 2)^2 \quad (3)$$

Shape drag coefficient C_x is calculated by the formula, as follows.

$$C_x = C_M - C_f \quad (4)$$

Type: V is test speed, L is the length of test model, $\nu = 0.99712 \times 10^{-6} m^2 / s$ is the kinematic

viscosity coefficient of water when the test temperature is 21.8°C , R_M is the total model resistance, $\rho = 997.94\text{Kg} / \text{m}^3$ is the density of water at the time of testing, S is total wet surface area.

The test results in each state are shown in Table 1.

Tab. 1 results of resistance test, Unit: N

$V/\text{m}\times\text{s}^{-1}$	1	2	3	average
0.54	2.1	2	1.9	2
1.12	8.9	9.1	9.3	9.1
1.51	14.4	13.9	14.6	14.3

In the experiment, the working state of 3D printing model is in good condition. The experimental data provides an important visual basis to verify the force of the prionace glauca 3D model in the flow field. Thus, it provides an important reference for the rapid development of the research and development of AUV.

Conclusion

The study focused on the process of 3D printing technology of prionace glauca. The process, with the formation of the 3D model, was carried out by accurate numerical description based on the specifications of the prionace glauca itself. The experimental model was used to do the relevant experiments to obtain relevant data after the fine processing and was consistent with the three-dimensional model and completed by 3D printing technology. The application of 3D printing provides a powerful proof for verification of mechanical properties of prionace glauca in flow field. The results show that:

1) 3D printing technology, which can be directly controlled by the computer model data, has been generated without any molding or mechanical processing, produce essential objects by increasing material technology. Therefore, the application of 3D printing is suitable for processing the complex body with high efficiency because of its advantage. It greatly shortens the product development cycle, improve productivity and reduce the production cost.

2) 3D printing takes an advantage of PLA plastic, environment-friendly biodegradable thermoplastic material that is taken as the common material of 3D printing of prionace glauca model, and use the method of segmented printing and splicing to print model. The printing fish is consistent with 3D model after micro correction, which will prepare the fish body surface and reduce the smoothness and deviation of natural fish.

3) The prionace glauca 3D model provides a strong proof to verify the mechanical properties of the prionace glauca in the flow field, and also provides a basis for further guiding the optimization design of AUV.

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