MAYA-aided sculpture design and ANSYS Finite Element Structural Analysis——A Case Study of a Public Sculpture in JiangBei New District of Nanjing

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Abstract. With the acceleration of urbanization in China, public sculptures have become landmarks of many communities or architectural complexes, and promoted cultural environments. Computer-aided public sculpture design combined with structural analysis has become a new creation mode. This study investigates computer three-dimensional aid design combined with computer-aided engineering based on the creation practice of a sculpture in Jiangbei (north of the Yangtze River) New District of Nanjing to improve design efficiency and design quality. The results have certain reference significance for the current digital public sculpture design.

1. Introduction
Computer 3D technology has been widely used in aid design, and creates important images of the sculpture design process. The commonly used software for sculpture design includes 3D Max, Maya, Mud box, Z brush, etc. Mud box and Z brush are suitable for sculpture of natural features, such as human body, jujube and rock. 3D Max and Maya apply to designing sculptures with abstract geometric shapes. In the 1980s, sculptors and programmers began to cooperate in sculpture design. The sculptors considered the realization of concepts such as scale, shape, dynamic and visual meaning in the context of environmental sculpture. The programmers considered follow-up matters such as materials, economy and process through calculation [1]. At the beginning of the 21st century, computer-aided design tools were applied to the concept design of Hyperbolic Hexagon sculpture and try 3D printed sculpture [2]. The current computer aided design (CAD) and computer-aided engineering (CAE) have formed a design flow which can help designers to perform tasks that cannot be performed in traditional design. It can not only create geometric shapes, but also detect and evaluate complex geometric space [3].

2. Method
With the aid of computer 3D modeling, sculptors focus on project conception. 3D technology provides a flexible imaging system to assist the creation process. Finally, finite element analysis technology can assist sculptors to verify the mechanical properties and safety factors of materials to improve the entire design. There are many practical cases of polygonal modeling sculpture in China, such as the model verification of clay horse sculpture by Du Hemin and Zhang Shumei in Xi’an Technological University. From the perspective of analyzing traditional hand-made sculpture modeling, reasonable Polygon modeling steps and wiring help to designers’ creation [4].
The case studied in this paper is the public sculpture of Jiangbei New District in Nanjing, “Pregnancy”, which was jointly created by Chen Liang (sculptor), associate professor of Nanjing Normal University, and Cao Yang (modeling designer), associate professor of Nanjing Normal University (Fig. 1). The sculpture is located in the Citizen Square, Jiangbei New District Intelligent Manufacturing Industrial Park, Pu Si Road, Nanjing. It was made of stainless steel 5mm thick through hand forging and mirror polishing to reflect the rich greenery of the park and the leisure interaction of the citizens. The sculpture is like a blooming corolla, and the petals support and protect the stamens that are about to become fruits, showing the hope and expectation. The lateral of the sculpture is an open pod filled with seeds, and conveys the joy of harvest. “Pregnancy” also reflects the location of the Jiangbei New District Intelligent Manufacturing Industrial Park. As the incubator of modern intelligent enterprises, the creative industrial park provides professional teams and attentive services for the introduction, construction, production, sales and listing of enterprises, supports and accelerates the birth of world-class intelligent enterprises, and implements intelligent manufacturing industry cultivation projects. Contemporary public art sculptures have gradually replaced traditional urban sculptures focusing on characters. Since the modernism period off “art in cities”, many works using modernistic visual language have emerged, which proposed new value standards for redefining urban space and shaping urban cultural image.

3. Modeling Process
The modeling of the sculpture “Pregnancy” is designed using Autodesk Maya. The styling of the sculpture is achieved by a polygonal tool from the outer contour. The lines are converted into polygonal planes, and several planes are smoothed into a dynamic shape (Figs 2-3). The dynamics in static sculpture are different from the movements in dance or animation. There is neither physical movement nor visual movement in the former. The shape, the inclination, deformation and distribution of patterns and the direction of agglomeration generate the “power” in line with “Gestalt” psychology, which conveys a visual psychology, instead of real movement. There are a variety of dynamic design languages: change of shape ratio, directed tilt of patterns, deformation, distribution overlap, stroboscopic motion,
and traces left by physical forces [5]. After modeling, the natural light rendering is simulated by the renderer of Maya to generate the design sketch and animation of the sculpture, so that the designer can preview the effect of the work and even improve the visual effect through secondary design (Fig. 4).

4. Finite element analysis

4.1. Data setting

After finalizing the sculpture design, the solid model established in Maya is stored as an IGES file and input into ANSYS for finite element analysis. The specific parameters are as follows:

- Sculpture height (Y axis): 5.57 m, length (X axis): 8.91 m, width (Z axis): 6.97 m;
- Steel model: 316L;
- Simulated total weight: 6529 kg;
- Earthquake magnitude 3-6 (vertical and horizontal);
- Basic wind pressure: value in fifty year;
- Snow load factor: 0.65 (once in fifty years).
4.2. Data analysis results

In magnitude 3-6 vertical earthquake, the deformation of the sculpture gradually increases from the root to the top and the maximum deformation size is 0.0041 m (Fig. 5).

In magnitude 3-6 horizontal earthquake, the deformation of the sculpture gradually increases from the root to the top and the maximum deformation size is 0.0081 m (Fig. 6).

As the main influencing factor, wind load influences the bearing capacity of the sculptural components. When the basic wind pressure is $W_0 = 0.40 \text{ kN/m}^2$, the deformation size is 0.0413 m (Fig. 7).

In the snow load of once-in-50-year, the deformation of the sculpture gradually increases from the root to the top and the maximum deformation size is 0.0156 m (Fig. 8).
The sculpture has multiple coupling ways [6]. The deformation gradually increases from the root to the top and the maximum deformation size is 0.0732 m (Fig. 9). The 316L steel has a tensile strength of 550n/mm² and the overall displacement deformation is less than 1.5%.

5. Conclusion
Sculpture creation through 3D animation software is a modelling method approaching the artists’ manual operation, and has an emotional shaping consciousness. Polygonal modeling method of MAYA is suitable for abstract sculptures composed of geometric shapes, which helps sculptors and modeling designers to exert their shaping ability and spatial imagination ability. ANSYS can provide more comprehensive multi-field analysis of sculptural design. Secondary development and parametric technology can enhance design efficiency and improve design quality. This case study is also a design flow practice—sculpture verification of computer aided design (CAD) sculpture combined with computer-aided engineering (CAE), which has certain reference significance for the current digital public sculpture design.

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