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RESEARCH ON FEATURE-BASED RAPID MODELLING METHOD FOR KILL-EXPLOSIVE COMBATANTS

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The accurate calculation of the power of explosive warheads determines the effectiveness of the weapon system in striking targets. The key to the accurate evaluation lies in the accuracy of modeling explosive warheads. The difficulty of modeling is the inability of the model components of explosive warheads to automatically adjust the parameters. A fast modeling method based on the features of explosive combat departments is proposed to address the above difficulties. Based on the structural analysis, the components of explosive warheads are classified and their features are analyzed. Combined with the relationship between components and features, they are divided into standard geometric features and combined features. Then the Boolean operation logic sequence is designed to build the combined feature modeling algorithm, to realize fast splicing of multiple features and automatically generate component data. Finally, a feature-based modeling and simulation system for explosive warheads is developed using Visua1 C# language and Wpf framework. The results show that the proposed method can realize fast and accurate modeling of features of the explosive warhead, laying a foundation for the accuracy of power calculation.

Keywords: Features, components, explosive warhead, feature modeling principle

1 Introduction

Explosive warhead is the most widely used type of warhead, which mainly relies on the fragments and shock waves formed by the explosion of the warhead to collide with the target, causing the target to ignite and detonate for destruction. With the progress and development of science and technology, modern warfare requires warheads large range, high power, high precision and multi-function. The requirements for the parameters of the warhead demand are getting higher and higher, and the structural requirements are more and more complex. The comprehensive design of the explosive warhead is becoming more and more urgent, it is necessary to quickly create a more reasonable preset scheme for high explosive warheads.

To study the rapid modeling method of warheads, Yin et al. [1] proposed using discrete models for fast modeling, dividing the warhead structure into five types of features. Then a grid generation algorithm mainly based on autonomously

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constructed algebraic methods was used for fast modeling of warheads. Wang et al. [2] used the CAD / CAE software to realize the combination of digital design and simulation technology of warheads. The structural design of ceramic tiles can be automatically optimized according to the requirements of tile strength verification standards and end effect analysis calculations. Based on the Matlab, according to the structural features and power parameter model of the broken warhead, the 6 basic features of the broken warhead were selected for the rapid design of the warhead [3].

A feature-based rapid modeling method is proposed here [4]. Based on the experience of weapons enterprises in the design of anti-explosive warheads, and fully considering the influencing factors such as fast, simple and automatic modeling [5], the structural characteristics of explosive warheads is analyzed. Taking the features and components as the object, the mathematical model is sorted to divide the features into standard geometric features and combined features. The logical sequence of Boolean operation is designed, and the feature modeling algorithm is constructed to realize the splicing automation of features and components. In this way, the model of an explosive warhead is established accurately and quickly, which lays a foundation for the accurate of Weili [6].

2 Materials and methods

2.1 Principles of explosive modeling and features of explosive warheads

Deplosive warhead is the most widely used warhead and is a key component of the weapon system to play its combat role and power. With the advancement and development of technology, the design requirements for explosive warheads have significantly increased, which has also extended the design cycle of explosive warheads. To shorten the design period of the explosive warheads [6], a feature-based fast modeling method is proposed. According to the structural analysis of the explosive warhead, the structure of the explosive components is sorted out. As the structure of the explosive warhead mainly considers the projectile body, the features of the projectile is analyzed. According to the classification of projectile features, the features are divided into standard geometric features and combined features according to whether the features require Boolean operations such as splicing and removal. Standard geometric features refers to the basic model that the modeling of the explosive warhead, while combined feature refers to the combined model composed [7] of Boolean operations such as addition and removal on the basis of standard geometric features. Through sorting out the mathematical logical relationships such as docking, overlapping and translation between the combined feature models, the combined feature modeling algorithm [8] is constructed. It is also the criterion for the overall composition of components and explosive warheads.

2.2 Structure analysis of the explosive warhead

Different high explosive warheads have different compositions [9]. From the perspective of components, it should be composed of fuses, elastic body, cartridge belt and charge, as shown in Fig.1. The projectile body can be divided into warhead, cylindrical part and bullet tail, as shown in Fig.2.

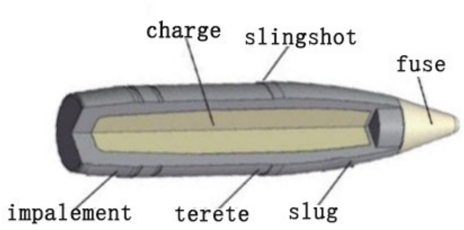

Fig. 1: Schematic diagram of the structure of an explosive bomb

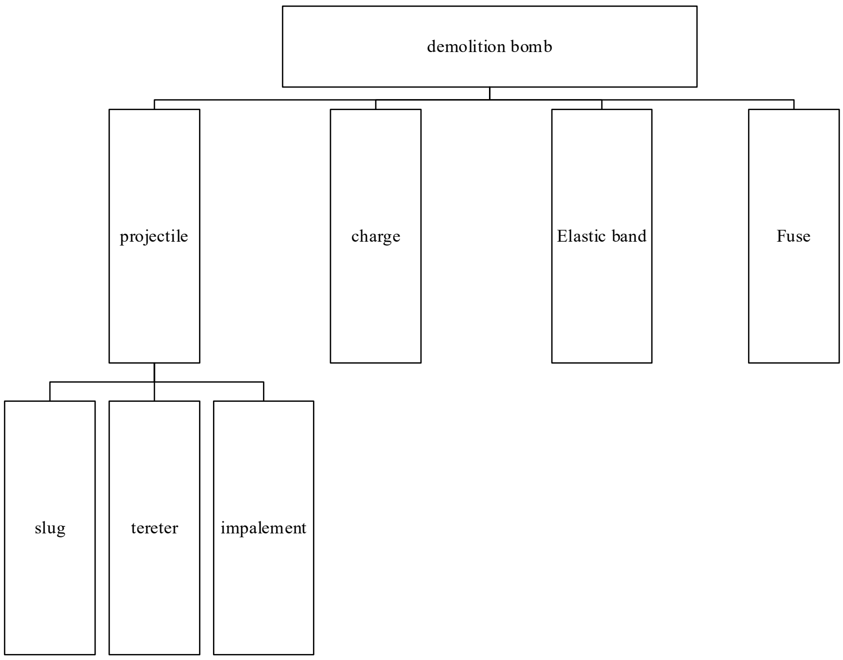

Fig. 2: Classification diagram of the explosive bomb structure

2.3 Feature analysis of the explosive warhead

The structure of the explosive fighting part mainly considers the projectile body. According to the analysis of the above explosive fighting structure, it can be seen that the projectile body contains a warhead [10], a cylindrical part and a tail. According to the classification of features, warheads can be divided into straight warheads and circular warheads. The standard geometric features are circular features, and the combined features are constructed separately according to the type of combination. The standard geometric features of a cylindrical part are divided into cylindrical features and circular features [11], while composite features are constructed separately based on the type of combination, as shown in Fig. 3.

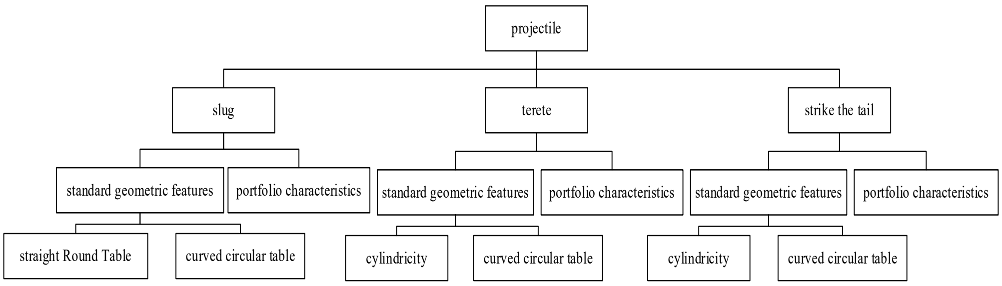

Fig. 3: Decomposition diagram of the projectile features

2.4 Feature modeling algorithm for explosive warheads

2.4.1 Standard geometric feature modeling algorithm

Based on the above analysis, the components of the high explosive warhead [12] can be divided into standard geometric features and combined features. The standard geometric features are not only the basis for the modeling of the combined features of high explosive warheads, but also the basis for the modeling of the components of high explosive warheads [13]. It is an indispensable part of the feature-based modeling of high explosive warheads. The specific standard geometric feature algorithm is as follows:

(1) Cylindrical feature

The parameters of the cylindrical feature are shown in Fig.4.

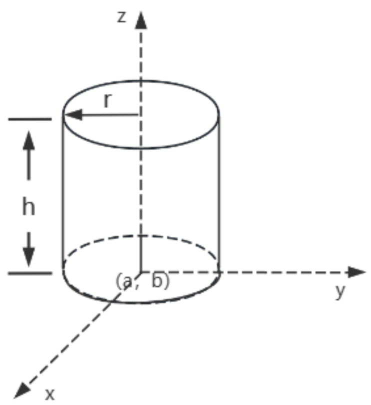

Fig. 4: Schematic diagram of the cylindrical feature

Mathematical model of the cylindrical feature:

$$(x-a)^2+(y-b)^2=r^2 \quad (1)$$

$$0 \leq z \leq h \quad (2)$$

where: (a, b) is the central coordinate of the bottom surface; r is the radius of the cylinder base surface, and$H$ is the height of the cylinder.

(2) Taper feature

The feature size parameters of the cone are shown in Fig. 5.

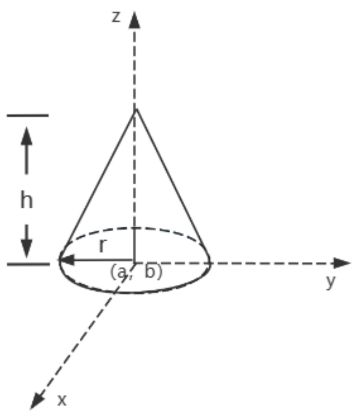

Fig. 5: Schematic diagram of the cone feature

Mathematical model of pyramidal feature:

$$(x^2+y^2)^{\frac{1}{2}}=(\frac{r}{h})*(h-z) \quad (3)$$

where: r is the radius of the base of the cone, and h is the height of the cone.

(3) Spherical feature

The feature size parameters of the sphere are shown in Fig.6.

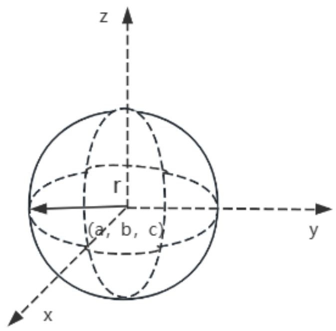

Fig. 6**:** Schematic diagram of the spherical feature

Mathematical model of spherical feature:

$$(x-a)^2+(x-b)^2+(x-c)^2=r^2 \quad (4)$$

where: *(a, b, c)* is the center coordinates of the sphere, and $r$is the radius of the sphere.

(4) Straight-line frustum feature

The linear frustum size parameters are shown in Fig.7.

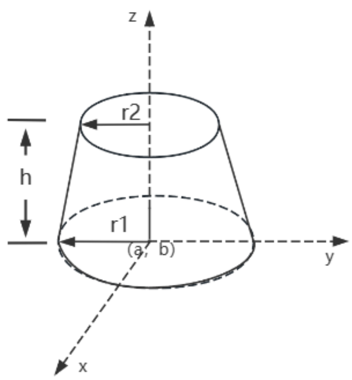

Fig. 7**:** Schematic diagram of the straight line frustum

Mathematical model of linear frustum feature:

$$(\frac{(r_2-r_1)}{h})*((x-a)^2+(y-b)^2)+z^2-z+{r_1}^2=0 \quad (5)$$

where: *(a, b, c)*are the center coordinates of the circle on the bottom surface of the round platform; r_1 is the radius of the bottom base; $r_2$is the radius of the top surface of the circular platform, and$h$is the height of the round platform.

(5) Arc frustum feature

The size parameters of the arc frustum features are shown in Fig.8.

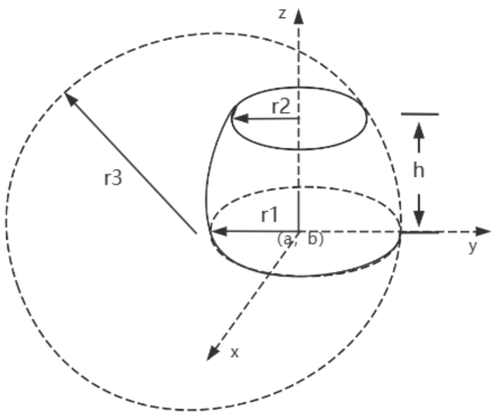

Fig. 8: Schematic diagram of arc round stage characteristics

Mathematical model of the arc frustum feature:

$$\left(\frac{(r_2-r_1)}{h}\right)*((x-a)^2+(y-b)^2)+z^2-z+{r_1}^2-\left(\frac{r_1r_2}{r_3}\right)*y=0 \quad (6)$$

where: $(a,b)$are the center coordinates of the circle on the bottom surface of the round platform; $r_1$is the radius of the bottom base;$r_2$is the radius of the top surface of the circular platform;$r_3$is the radius of the arc, and$h$ is the height of the round platform.

2.4.2 The modeling algorithm of combined features

According to the diversity of explosive warheads, combined features [14] are created to a warhead model. Based on the Boolean operation of adding and removing, combined features are the key to create components [15], which is more in line with the component structure of the explosive warhead. The modeling process of the combined features is shown in Fig. 9, and the specific modeling principle for the combined features is as follows:

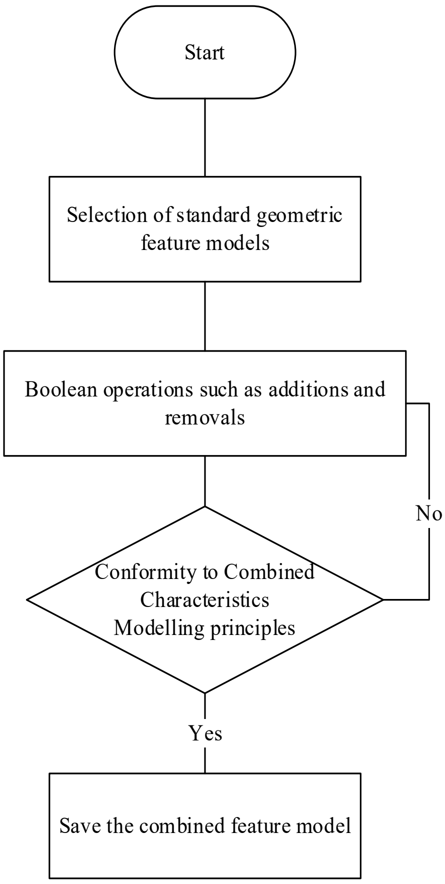

Fig. 9: Flowchart for the combined feature modeling

(1) Coaxial relationship: the axis of all component models or overall models should be in the same horizontal straight line;

$$x_1 = x_2 = x_3 = \ldots\ldots = x_n \quad (7)$$

$$y_1 = y_2 = y_3 = \ldots\ldots = y_n \quad (8)$$

$$z_1 = z_2 = z_3 = \ldots\ldots = z_n \quad (9)$$

where: $(x_1, y_1, z_1), (x_2, y_2, z_2) \cdots (x_n, y_n, z_n)$are the axis coordinates of each model;

The formula for the cylinder axis is as follows:

$$(x_3, y_3, z_3) = (\frac{(x_1+x_2)}{2}, \frac{(y_1+y_2)}{2}, \frac{(z_1+z_2)}{2}) \quad (10)$$

where: (x_1, y_1, z_1) and $(x_2, y_2, z_2)$are the center coordinates on the two bottom surfaces of the cylinder;

The formula for the cone axis is as follows:

$$(x_3, y_3, z_3) = (x_2, y_2, \frac{(z_1+z_2)}{2}) \quad (11)$$

where: (x_1, y_1, z_1) are the coordinates of the cone vertex; (x_2, y_2, z_2) are the center coordinates of the cone bottom surface.

The formula for the frustum axis is as follows:

$$(x_3, y_3, z_3) = (\frac{(x_1+x_2)}{2}, \frac{(y_1+y_2)}{2}, \frac{(z_1+z_2)}{2}) \quad (12)$$

where: (x_1, y_1, z_1) and (x_2, y_2, z_2) are the center coordinates on the top surface and the bottom surface of the circular platform.

(2) The relationship between the cross-section distances at the connections: The distance between the adjacent section connections of all component models or overall models is 0;

$$x_1 = x_2 \quad (13)$$

$$y_1 = y_2 \quad (14)$$

$$z_1 = z_2 \quad (15)$$

where: (x_1, y_1, z_1) and (x_2, y_2, z_2) are the midpoint coordinates of the adjacent sections of each model.

(3) The relationship between the cross-sectional dimensions at the connections: the surface area of the corresponding section at the connections of all component models or overall models is equal;

$$S_1 = S_2 \quad (16)$$

where: S_1 and S_2 are the surface areas of the adjacent section at the connection of each model.

(4)Parallel relationship at the section connections: the corresponding sections of all component models or the whole model are parallel;

$$n_1 \cdot n_2 = ||n_1|| \, ||n_2|| \cos\theta \neq 0 \quad (17)$$

where: n_1 and n_2 are the normal vectors of the cross-section at the connections of the corresponding sections; $||n_1||$ and $||n_2||$ are the module lengths of the normal vectors of the sections at the corresponding section connections, and θ is the angle between n_1 and n_2.

3 Results and analysis

A digital feature modeling system [8] was developed based on the rapid feature modeling method of high explosive warhead by using the Visua1 Studio 2019 platform, the Visua1 C# language and WPF framework [16]. The main interface of the system is shown in Fig. 10. The main function of the system is to model the features according to the structure of the high explosive warhead, and realize the creation of anti-explosive warhead parts by constructing the features of the high explosive warhead. The creation process is shown in Fig.11.At the same time, the created model is connected to the database through the SQL language [17]. The created model information is stored in the database to complete information exchange, and the view is displayed through WPF, which is convenient for designers to intuitively verify the design results.

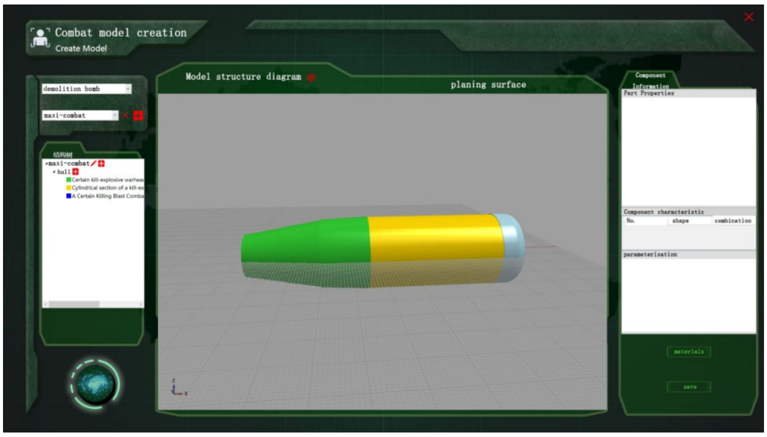

Fig. 10: Creation interface of the high explosive warhead

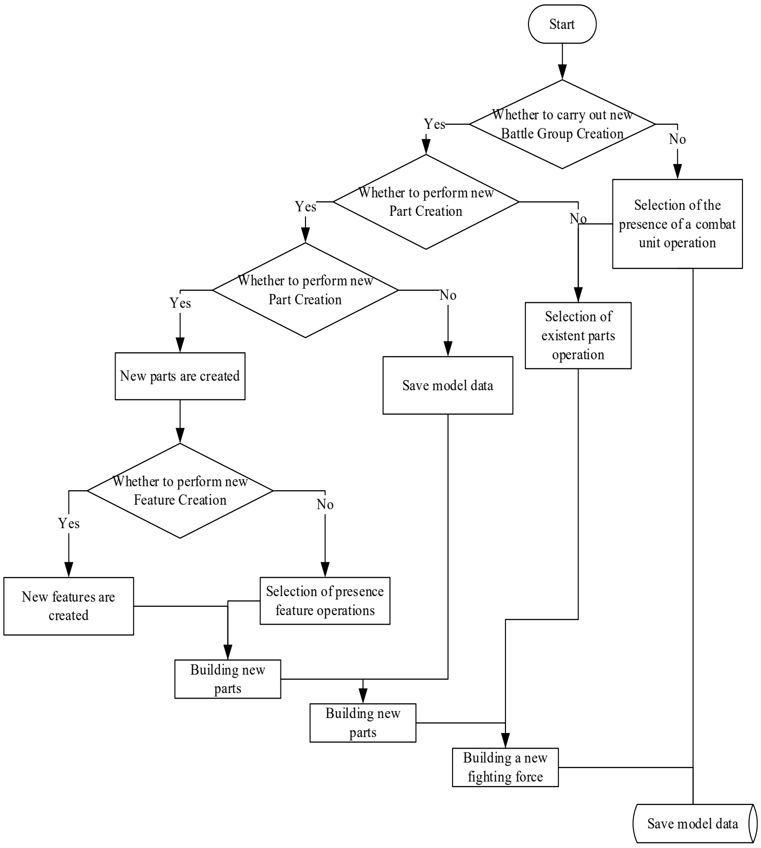

Fig. 11: Modelling and flowchart of the high explosive warhead

Taking a high explosive warhead as an example [10], it has a total length of 326 mm, a total mass of 13.57 Kg, and a total volume of $3589 cm^3$. The warhead charge is cylindrical with a total mass of 3.41 Kg. The digital feature modeling system is applied for feature modeling, and the feature modeling information is compared with the test data, as shown in Table1.

Table 1

Comparison of the modeling information and experimental data

Project	Experimental data	Modeling information	Error analysis
Battle Chief (mm)	326	324	0.61%
Total Mass (Kg)	13.57	13.51	0.44%
Total volume (cm^3)	3589	3579	0.27%
Combat Total Charge Mass (Kg)	3.41	3.38	0.87%
Total Shell mass (Kg)	3.62	3.59	0.82%

The results in Table show that the difference between the test data and the modeling data is not more than 10%, indicating the feasibility of the feature-based rapid modeling method. It provides a new idea for the rapid design of the high explosive warhead. At the same time, power parameters such as the type of explosive charge, charge density, number of natural fragments, initial velocity of fragments along the axis, direction angle of fragment dispersion, and angle of fragment dispersion will also be stored, laying the foundation for calculating the power of explosive warheads.

4 Conclusion

(1) A fast modeling method for explosive warheads is proposed. Based on the analysis of the structural features, the components of explosive warheads are classified. The logic sequences of Boolean operation are designed, and a composite feature modeling algorithm is constructed to achieve fast concatenation of multiple features, automatic generation of component data, and fast design of explosive warheads.

(2) A digital feature modeling system is developed using Visua1 C # language and Wpf technology, and a certain explosive warhead is used as an example for digital feature modeling. Through example verification, it shows that the model built by the digital feature modeling system is accurate and the results have high credibility, laying a foundation for the accuracy of power calculation.

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