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# Study on Three-Dimensional Design of Hydraulic Protection of Oil and Gas Pipeline Based on Database

# STUDY ON THREE-DIMENSIONAL DESIGN OF HYDRAULIC PROTECTION OF OIL AND GAS PIPELINE BASED ON DATABASE

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**Abstract.** The traditional method of design of hydraulic protection is completed by CAD software. The draft is drawn by hand in topographic map, profile map and column map. This design approach is inefficient and prone to error. In this paper, the three-dimensional design method of hydraulic protection is studied based on database. In the following, the key technologies are discussed, including the establishment of the knowledge model, database structures, quantities and the amount of material and three-dimensional modelling algorithm. Through practice applied in multiple projects, this kind of design method achieved good effect. the designers free themselves from the tedious work of drawing, calculations and statistical work of liberation. The efficiency and quality are greatly improved in using the digital design module.

## 1. Overview

As an important part of oil and gas pipeline working drawing, hydraulic protection makes great significance to pipeline safety, environmental protection, and preventing soil erosion[1].Traditional design of hydraulic protection， based on alignment sheet，realized the design results with AutoCAD[2].

Designers need to measure the parameters, such as length, slope, width, and so on, after reading the information on strip chart and profile. Designer also need to select the corresponding hydraulic protection applying to general charts, mark it on the drawing, and manually calculate quantities and the amount of material [3]. This work is very onerous, and has the following disadvantages.

It's difficult to determine the design parameters. For example, the slope length measured in the profile, due to the different vertical and horizontal ratio, needs to be converted to get the actual length.

- It's a time-consuming work to mark the hydraulic protection. All the information needs to be manually marked on the flat and profile after determining the type of protection and design parameters.
- The quantity will be required for manual calculation, and it's too huge and error-prone to easily summarize[4].
- Modifications make a lot of difficulties. Every change must be redrawn, recalculated and recounted.

Based on the above-mentioned factors，detailed design of traditional hydraulic protection takes too much time and human resource. Obviously, with the development of oil and gas pipeline engineering

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construction, this method cannot meet the needs of the production. As a result, a three-dimensional design of hydraulic protection based on database arises at the historic moment.

## 2. Main Techniques of Parameter Design of Hydraulic Protection

### *2.1. The establishment of a knowledge model*

Hydraulic protection design is mainly based on ***Code for design of oil and gas transportation pipeline hydraulic protection (SY 6793-2010).*** Its purpose is to meet the requirements of environmental protection and take some measures to prevent soil erosion. All projects in the detail design stage, according to different damage factors, need to prepare the typical drawings. It is a direct basis for guiding detail design and construction. To achieve parametric design, typical drawings need to be transformed into knowledge models that computer can realize[5].

Table 1. Part of the knowledge model of parametric design

| **Protection type** | Protection form | Single parameter (*mouse interac- tion* ) | Single parameter (*Interface Input* ) | Engineering parameters | Result type | Formula |
|---|---|---|---|---|---|---|
| **Slope protection** | Masonry slope protection | Slope length (L) | With or without water | ROW width<br>Pipe diameter (D)<br>Depth (H) | Masonry volume （m³） | (Row+1or2)×(0.9+（0.3×L+（0.4+0.7）×0.3/2）)×1.15+ Masonry volumes in table （D,H） |
| | Sack soil slope protection | Slope length (L) | With or without water | ROW width<br>Pipe diameter (D)<br>Depth (H) | Soil volume （m³）<br>Number of sack (round up) | (Row+1)×(1.0+ QTY in table （L）)+ Soil volume in table （D,H） |
| | Dry stone slope | Slope length (L) | With or without water | ROW width<br>Pipe diameter (D)<br>Depth (H) | Stone volume （m³） | (Row+1)×(1.0+ QTY in table （L）)+ Stone volume in table （D,H） |
| **Cut-off wall** | Masonry cut-off wall | Gradient<br>Slope length | Spacing between walls | Depth (H)<br>Widening amount of the bottom (B) | Masonry volume （m³） | b=h×0.25+0.4 Area=（a+b）×h/2；The axis of cross-section =（2×（D/1000+B+0.2）+2×h×0.2）/2 Trench volume = Area×The axis of cross-section Pipe volume =PI/4×(D/1000)^2×b；Masonry volume =Trench volume -Pipe volume |

### *2.2 .Data base*

Parameter design of hydraulic protection based on database needs to set up a database that used to store the pipeline parameter, engineering parameter, material database and design parameter [6].

Table 2.Three-dimensional digital model of hydraulic protection

| Type | Content | | Code | Comment |
|---|---|---|---|---|
| **Engineering parameter** | Curvature radius and Angle boundaries | Curvature radius of clod bend | Lwd | Relate to mileage |
| | | Curvature radius of hot bend | Rwd | |
| | | The elastic bending angle (*lower limit of angle* ) | Tfa | |
| | | Clod bending angle *(lower limit of angle* ) | Lwa | |
| | | Hot bending angle (*lower limit of angle* ) | Rea | |
| | Length of pipeline | | Gangguanlen | |
| | Parameters of pipe trench | Depth | H | |
| | | Widening amount of the bottom | B | |
| | | Soil slope | Th | |
| | | Stone slope | Sh | |
| | | Rocky overbreak | Sch | |
| | | Stratification of soil and stone | Tsl | |
| | Area grade and design coefficient | Area grade | Ag | |
| | | Design coefficient | K | |
| | Pipeline and anti-corrosive coating | Pipeline diameter | D | |
| | | Pressure | P | |
| | | Wall thickness | Thk | |
| | | Steel grade | Sg | |
| | | Pipeline form | St | |
| | | Anti-corrosive type | Ant | |
| | | Anti-corrosive grade | Anl | |
| | Width of right of way | Width of right of way | Row | |
| **Symbol parameters** | Name | | Name | |
| | Reference drawing No. | | Tuhao | |
| | length | | Lgth | |
| | Wide | | Wide | |
| | Height | | Height | |
| | Slope | | Vangle | |

| Type | Content | Code | Comment |
|---|---|---|---|
| **Monomer interaction parameters** | Depth | Maish | |
| | Picked coordinates | PointX，PointY | |
| | Midline of plane | Pmzx | |
| | Vertical line | Gx | |
| | Ground line | Dmx | |
| **Output parameters** | Quantities | Gcl | |
| | The amount of material | Cll | |

### *2.3. Algorithm of quantities and material*

In determining the length of masonry slope protection, it will automatically calculate the quantities according to the typical drawing. Both formula and data table will be realizable to calculate the quantities. The formula calculating method is adopted in simple formula. While looking up data table is a better way when the quantities formula is complex or depended on experience.

Quantities of masonry slope can be calculated as follow:

Quantities =(Row+1 or 2)×(0.9+（0.3×L+（0.4+0.7）×0.3/2）)×1.15；

The masonry volume in the trench can be found in the data table by reading diameter and trench depth.

Table 3.Volume of masonry slope in trench ($m^3$)

| D（mm） / H（m） | 406 | 508 | 610 | 660 | 813 | 1016 | 1219 |
|---|---|---|---|---|---|---|---|
| 1.5 | 3.0 | 3.0 | 3.1 | 3.1 | 3.2 | 3.2 | 3.1 |
| 2.0 | 4.5 | 4.6 | 4.7 | 4.8 | 4.9 | 5.0 | 5.1 |
| 2.5 | 6.3 | 6.4 | 6.6 | 6.7 | 6.9 | 7.1 | 7.3 |
| 3.0 | 8.3 | 8.5 | 8.7 | 8.8 | 9.1 | 9.4 | 9.7 |
| 3.5 | 10.6 | 10.9 | 11.1 | 11.2 | 11.6 | 12.0 | 12.4 |
| 4.0 | 13.1 | 13.4 | 13.7 | 13.9 | 14.3 | 14.9 | 15.3 |
| 4.5 | 15.9 | 16.3 | 16.6 | 16.8 | 17.3 | 17.9 | 18.5 |

Calculation of the material is similar to the quantities. After automatically calculating the quantities, according to the typical drawing and material index, the quantities can be broken down into materials. Each material can also be summarized. No more details here.

### *2.4 .3D modeling*

#### *2.4.1. 3D modeling method.*

3D parametric modeling of hydraulic protection can be divided into three steps [7]:

- Component-oriented parametric modeling is to decompose hydraulic protection into several components. Further decomposition or subclass is used on complex components to get the minimal component. Construction characteristics are described by mathematics, and they compose the parametric model of the component. Different component can be obtained by changing the parameter.
- Location and combination of the component is to combine into a complex three-dimensional entity according to rules of interaction and location parameter.
- Rendering technology bases on 3ds Max platform. Computer reads the database of hydraulic parameters and automatically translates them into identifiable data clusters - coordinates, surface structure, texture, smooth method and so on. These clusters can be drawn and edited by 3ds Max.

#### *2.4.2. The decomposition of hydraulic structure.*

The decomposition of hydraulic structure includes two layers - Logic decomposition and physical decomposition. Logic layer decomposes the structure according to hydraulic construction rules. For example, masonry slope can be decomposed into the upper platform, the lower foundation and the slope body. According to the needs of parametric modeling, the physical layer decomposes complex components into minimal components. The decomposition results have better modeling features. The specific method is as follows:

- Fully refine the similarity of components, and form strong representative parent.
- Tessellate the strongly changing part of the parent to obtain diverse and scalable subclasses.
- Take example of masonry slope protection. The slope body can still be subdivided into surface, scuppers and filter layer.

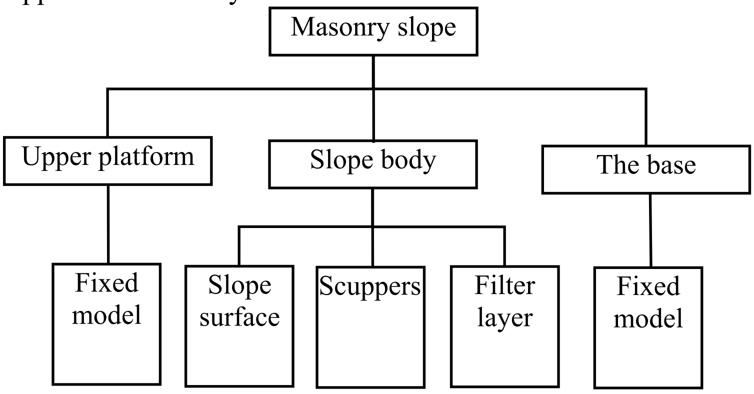


Figure 1.The structure of masonry slope

*2.4.3. Parametric modeling of component.*

In the design of parameter model, the parameter should not be repetitive or conflicting. It must be well-defined. There are 3 types of parameters in three-dimensional model of 3ds Max: the geometric parameters, orientation parameters and texture parameters.

Geometric parameters are used to describe the geometric structure of component characteristics. It has two design methods. The first is section design and midline lofting. The second is the simple entity design. The slope body can be obtained by describing the section and then stretching.

Orientation parameters are used to indicate the relative position of components and component itself. The parameters change with the different interaction rules among components.

Texture parameters are used to indicate the material of the component. It contains texture channel and tile parameter. Texture channel and tile parameter are, respectively, used to specify the map content and mapping ratio.

*2.4.4. The orientation and combination of components.*

In the design of oil and gas pipeline hydraulic protection, the pipeline is the orientation basis in the world coordinate system of hydraulic protection. Mileage value is the orientation basis in relative coordinate of component model. The first code of pipeline corresponds to origin of coordinate. Mileage value of the component needs to be converted to world coordinate to relocate. Orientation of components is divided into horizontal and tangential orientation. Horizontal orientation refers to the lofting line of components being parallel to the pipeline. It will be finished only by parallel movement according to starting mileage and vertical offset value in the direction of the center line. Tangential orientation refers to being tangent to the lofting line. It will be finished by calculating the tangential direction, beam bottom coordinates, and then rotating and moving according to the calculating result.

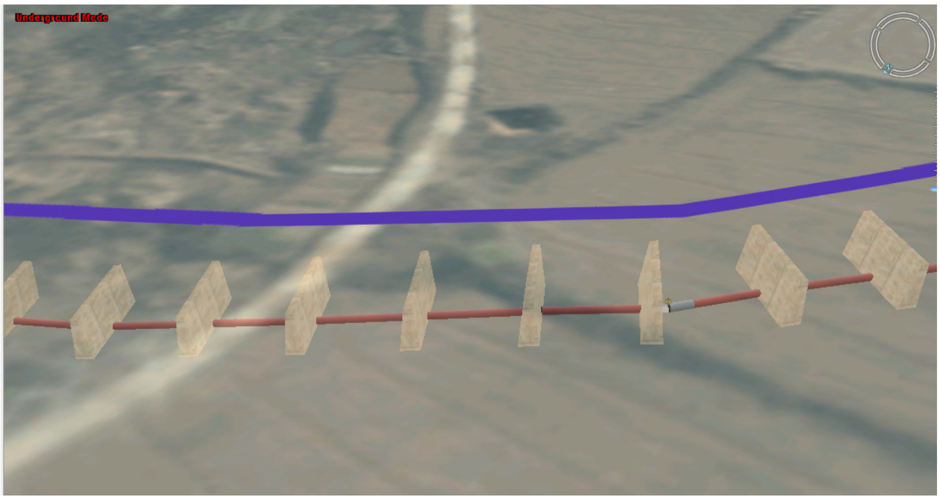

Figure 2. Cut-off walls composition rendering

**3.Epilogue**

The hydraulic protection design based on database frees designer from tedious drawing, calculation and counting. It helps designers pay more attention to design, and greatly improves design efficiency and quality. Knowledge models digitize the typical drawing of hydraulic protection. It makes the maintenance and reuse of typical drawings more convenient. In addition, the outcome of parametric design raises the level of digital pipeline design. It becomes easy to manage the full life cycle. It can also be easily imported into other systems, such as GIS and three-dimensional display system[8].

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