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Application of Hyperboloid of One Sheet in Real Life

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Abstract
The curved surface generated by a family of rectilinear motion is called ruled surface in geometry, and the straight line in motion is called rectilinear generator. Hyperboloid of one sheet is exactly a typical ruled surface, which has two families of rectilinear generator. This paper probes into the application of hyperboloid of one sheet in constructional engineering, electric power engineering, mechanical processing, communication engineering and daily life, and further studies the method of making hyperboloid of one sheet by hand.

Key words: Hyperboloid of one sheet; Rectilinearity; Application; Handmade

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INTRODUCTION
Analytic geometry has been promoting the development of mathematics; moreover, it has entered a new development stage in both content and method. The phenomenon of straight line contained in curved surface, curve formed by straight line does not seem to exist, but this kind of curved surface--ruled surface indeed exists in geometry. In life, for instance, if you swing a stick at will, the movement trajectory plane of the stick will contain straight lines, and such a curved surface is made up of straight lines. Ruled surface is an important concept in non-Euclidean geometry. Its application in real life is very common, and there are mathematical models of it in architecture, hydraulic engineering and daily life.

Definition 1 (Lv & Xu, 2001): the curved surface generated by a family of rectilinear motion is called ruled surface in geometry, and the straight lines in motion are called rectilinear generators.

Definition 2 (Wang & Fu, 1999): in rectangular coordinate system, the curved surface represented by the equation $\frac{x^2}{a^2}+\frac{y^2}{b^2}-\frac{z^2}{c^2}=1$ is called a hyperboloid of one sheet, in which, a,b,c is any positive constant.

Rectilinearity of hyperboloid of one sheet (Zhang, Gao, & Wang, 1995):

Property 1: Hyperboloid of one sheet is a ruled surface, which is a curved surface generated by rectilinear motion.

Property 2: Any two rectilinear generators of the same family are in the different planes.

Property 3: Any rectilinear generator will intersect all straight-line generators of another family.

Property 4: For any point on a hyperboloid of one sheet, one rectilinear generator in any one of the two families will pass through the point.

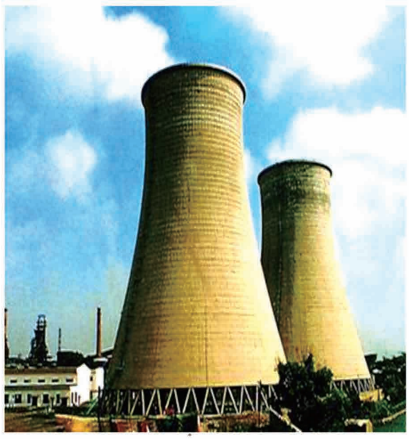
1. APPLICATION OF HYPERBOLOID OF ONE SHEET IN ACTUAL LIFE
Hyperboloid of one sheet is a typical quadric ruled surface, which is often employed in the design of building and mechanical parts. Based on the properties of rectilinear generator, the structure in bending shape

can be made with straight component as skeleton. The reinforced bars are placed along the rectilinear generators, and the intersection points of the two groups of rectilinear generators are fixed, so as to obtain a very solid building. Such nice properties make it widely used in life.

1.1 Canton Tower

Canton Tower, also known as "Slim Waist", is composed of the tower body and antenna mast, and the whole tower body is a kind of similarly pierced steel structure frame formed by 24 straight steel columns, as shown in Fiugre 1. Reinforced columns are erected from bottom to top, which cross with each other to form a hyperboloid of one sheet. By virtue of the rectilinearity of hyperboloid of one sheet, the fixed shell is constructed with intersecting straight steel bars. If erected vertically, the steel bars will be unstable due to heavy load, thereby failing to achieve the desired effect. This method not only saves material, but also enhances the stability, which is a very successful application of mathematical model.

Fiugre 1
Canton Tower



Fiugre 2
Cooling Tower

Fiugre 3
Planetarium

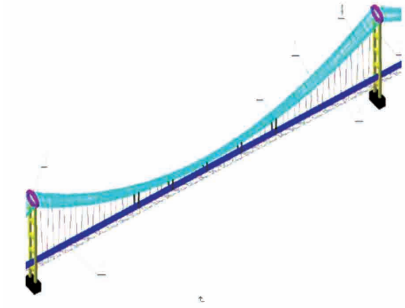
1.2 Cooling Tower

When the water tower is built with vertical wooden poles, the building constructed will be damaged by a very small load if these wooden poles are placed vertically, so it is very unstable. However, if the poles are placed to form a uniparted hyperboloid (namely, two families of rectilinear generators), and their points of intersection are linked together, a very slim but quite solid building will be constructed – hyperboloid of one sheet. Therefore, the design principle of the shape of most cooling towers is the hyperboloid of one sheet (Fiugre 2), which has obvious advantages of rapid convection and heat dissipation. Based on its special shape (small in the middle, large at both ends), the maximum utilization of resources and energy can be achieved. Because of the rectilinearity of rotating one-sheet hyperboloid, the reinforcing steel bars can be arranged along the rectilinear generators when the shell of cooling tower is built. Compared with erecting the steel bars directly on the ground, the joints formed by intersecting steel bar can obtain better mechanical properties, which can not only enhance the overall structure stability, but also reduce the breakage of steel bar and other materials to a certain extent, thus achieving the effect of building curved surface with straight steel bar.

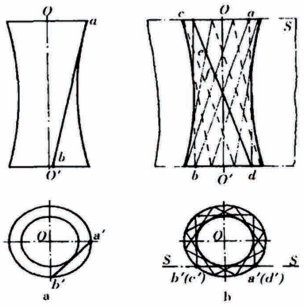
Compared with other cooling towers, the cooling tower with hyperboloid of one sheet is provided with the distinct advantages below: 1. small floor space and less water loss; 2. good ventilation effect and smooth air flow; 3. economy of materials. Compared with mechanical cooling tower, it has the advantages of energy saving, easy maintenance and etc. The cooling tower with hyperboloid of one sheet will be increasingly common along with the improvement of science and technology.

1.3 Planetarium

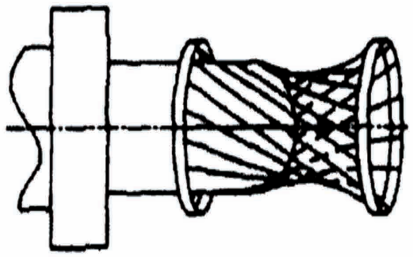
The McDonough Planetarium in St. Louis Forest Park (Fiugre 3) is a typical example of uniparted hyperboloid. At any given time of one day, sunlight splits the tower in half along the rectilinear generators, which seems like a tilted wine glass from a distant place, thus bringing people with endless imagination and joyful visual enjoyment.



Fiugre 4
Suspension Bridge



Fiugre 5
Cutaway View of Aluminum Foil



Fiugre 6
Springwire Jack

1.4 Suspension Bridge

The steel ropes arranged in the old-style suspension bridge are vertical and parallel, with poor wind resistance, thus resulting in the low safety coefficient of such suspension bridge. By reference to the structural structure of Motuo Rattan Bridge in Tibet, China, the steel ropes are arranged along the rectilinear generators to form a suspension bridge with hyperboloid of one sheet (Fiugre 4) by making full use of its rectilinear principle according to the long-span structural design concept of "Tensegrity". Through fixing the joints, the lateral and torsional resistance of suspension bridges is greatly improved. Moreover, the structure also makes it easier to maintain and replace the cable ropes (Su, 2015). This structure has solved the problem of wind resisting stability for most suspension bridges. So far, the suspension bridge of this structure is more in line with the technical requirements of wind resistance.

1.5 Aluminum Foil Crosscut

During the cutting process of moving aluminum foil, the original spiral blade can only cut at one point, but tear other parts, which cannot achieve the cutting effect. By taking advantage of the rectilinearity of hyperboloid of one sheet, we changed the original cylindrical helical rotary blade into a rectilinear rotary blade without changing the original structure of the machine. As shown in Fiugre 5, this could make the two cutting edges work together and achieve a good cutting effect, and the rectilinear blade is easier to manufacture and grind compared with the original blade. Therefore, the cutter with hyperboloid of one sheet is provided with strong applicability and rationality. Nowadays, there are more types of cutting tools with hyperboloid of one sheet, and the design of multi-blade has been applied in lawn mower and other fields.

1.6 Nozzle

For some injection with strict requirements, the nozzle is often designed to be a hyperboloid of one sheet. The transversal line of the nozzle with hyperboloid of one sheet along the axis is hyperbola. When the liquid flows along its shape, it will not be sprayed unevenly due to the change of kinetic energy and potential energy. Therefore, uniform injection can be achieved. Nowadays, the nozzles with hyperboloid of one sheet have been applied in printing, dyeing and painting industries.

1.7 Springwire Jack

In the communication industry, the design of springwire jack of connector (Fiugre 6) is also based on the forming principle of hyperboloid of one sheet. It is generally composed of springwire, inner sleeve, front outer sleeve, and rear outer sleeve (sometimes the overall outer sleeve). Springwire jack is to make a number of (generally 5 at least) independent elastic wire inside the inner sleeve a certain angle with the axial direction of inner sleeve, and fasten the springwire onto the inner sleeve at both ends with outer sleeve through the interference fit among inner sleeve, springwire and outer sleeve after bending it to the outer wall of inner sleeve at both ends. The elastic wire in the inner sleeve is just the generatrix forming the hyperboloid of one sheet, so this jack is called the one-sheet hyperboloid jack, referred to as the springwire jack for short.

2. THE MAKING OF HYPERBOLOID MODEL OF ONE SHEET

It is necessary to prepare bamboo sticks, marker pen, rubber bands, ruler and etc. for the making of hyperboloid of one sheet. First, determine how many bamboo sticks are used in each direction (16 groups are selected in this figure, a total of 32). If the number of bamboo sticks in each direction is denoted as n, then the total number of bamboo sticks is $2n$. Then, make n holes on the prepared thick card paper, with the distance between each two holes to be 2-3 *cm*. Secondly, tie *2n* bamboo sticks with a rubber band in a crossed shape, and insert one of the pair of bamboo sticks into the corresponding hole on the card (keeping the direction unchanged). Step 3: tie the rubber band at the adjacent cross point of bamboo sticks, and try to arrange the rubber band neatly in this process. After tying a circle, pull up the rubber bands, and then tie

rubber bands at the adjacent cross point. Finally, connect the left and right ends with rubber bands in the same way as above to complete its making. (It is essential to keep the directions of the two groups of bamboo sticks always the same)

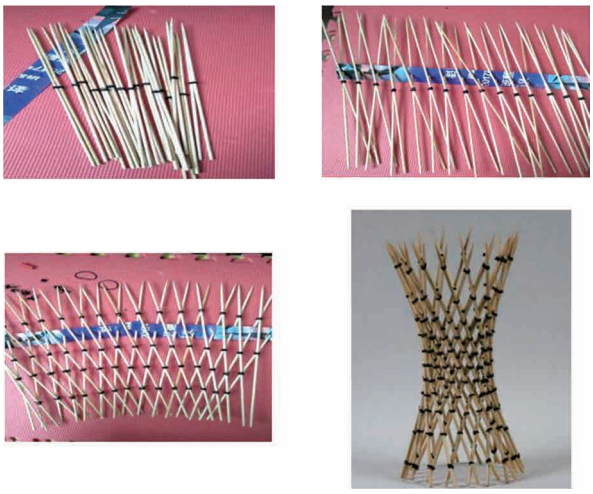


Figure 7
Working Drawing of Hyperboloid of One Sheet

CONCLUSION

Hyperboloid of one sheet has its special properties in geometry, which is a curved surface generated by rectilinear motion. Any two rectilinear generators of the same family are in different planes; any of its straight lines intersect all straight lines of another family; for any point on the hyperboloid of on sheet, there is one rectilinear generator in the two families of rectilinear generators passing through the point, and it is just because of these characteristics that make it widely used in real life.

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