

Parametric Modeling of Hybrid type single Reticulated Dome

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Abstract. To improve the application functions and structure characteristics of single reticulated dome, we divide it into two parts: upper layer and lower layer, and construct them with two different typical single reticulated domes respectively to form six hybrid single reticulated domes. According to the characteristics of node generation and element connection, we put forward six hybrid single reticulated domes modeling methods and complete corresponding modeling macro programs by using the ANSYS Parametric Design Language (APDL), and achieve the shell modeling in given design parameters. The modeling examples show that the method is simple, efficient and practical. This method may facilitate structure force analysis and optimization design of different types and different parameters models by using ANSYS software, which also offer a kind of effective method to expand the reticulated dome type.

Introduction

Shell structure bears beautiful appearance, appropriate mechanical property, large coverage as well as many characteristics of both rod-system and thin-shell construction, thus it possesses broad application prospects and developing potential. Considering its structural features and functions, we put forward six hybrid single reticulated dome models, and produced a method of structure optimization and model selection. However, due to the large number of nodes and elements of shell structures, the variation of span, rise high, meshing size, type and other parameters can influence the internal force redistribution of shell structures. Therefore, with modeling methods and APDL software of shell structure by researching the distribution of elements and nodes, the design efficiency can be greatly improved and the analyzing cost can be reduced at the same time[1-4].

In this paper, the node and rod element generation method and macro program of six hybrid reticulated domes are put forward by using APDL [5]. Users can easily get the required parametric modeling just by inputting parameters such as the span S , rise high F , number of circle hoop symmetry areas kn , radial node cycles nx and the upper structure laps ns . It laid a good foundation for structural analysis and optimization design.

Geometric Descriptions

The main geometric parameters of hybrid reticulated dome include: S , F , kn , and nx , ns . The global angle ($Dpha$) of the two neighboring circle radial nodes and curvature radius of sphere R are calculated by Eq. 1 and Eq. 2. (as shown in Fig. 1 and Fig. 2).

$$Dpha = \begin{cases} \arctan \frac{S}{2nx} \sqrt{R^2 - \left(\frac{S}{2}\right)^2} & \frac{F}{S} \neq \frac{1}{2} \\ \frac{90}{nx} & \frac{F}{S} = \frac{1}{2} \end{cases} \quad (1)$$

$$R = \frac{S^2}{8F} + \frac{F}{2} \quad (2)$$

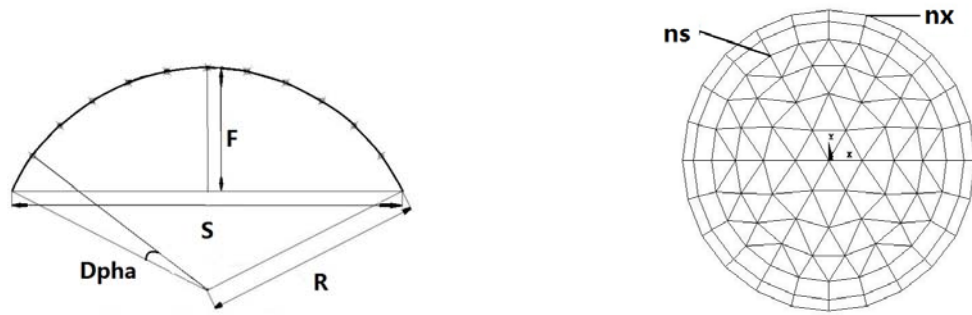


Fig.1. Diagram of hybrid reticulated dome Fig. 2. Top view of hybrid reticulated dome

Six types of Parametric Modeling of Hybrid type single Reticulated Dome

In the spherical coordinates span S , rise high F , number of circle hoop symmetry areas kn and radial node cycles nx are given, the curvature radius of sphere R and $Dpha$ ($^\circ$) is calculated. The node number and coordinates in each circle are given from inside to outside in order. Rod elements are generated by connecting nodes after node created. Let vertex be number 1. Applying loads on nodes whose number is less than the start node number of outside shell and applying restriction on other nodes. Bar type, material properties, real constant, and so on were applied to analyze the force of structure.

Kiewitt-Ribbed Hybrid Dome(As show in Fig. 3)

The upper structure(Kiewitt type) node coordinates: The coordinates of apex are $(R,0,90)$ which numbered as 1. The j -th node at the i -th circle is numbered as $1+kn \times (i-1) \times i/2 + j$ and its coordinates are $x=R$, $y=(j-1) \times 360/(kn \times i)$, $z=90-i \times Dpha$.

The lower structure(Ribbed type) node coordinates: Build nodes outward from the $ns+1$ circle, the j -th node at the i -th circle is numbered as $1+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko + j$ ($ko=(ns+1) \times kn$, the same below) and its coordinates are $x=R$, $y=(j-1) \times 360/ko$, $z=90-i \times Dpha$.

Elements connection of the upper structure: The circular elements at the i -th circle and j -th ($(1 \leq j \leq kn \times i - 1)$) symmetric areas are generated by connecting the node $1+kn \times (i-1) \times i/2 + j$ and the node $1+kn \times (i-1) \times i/2 + j + 1$. Elements at the last symmetric areas ($j=Kn$) of each circle are generated by connecting the last node $1+kn \times (i-1) \times i/2 + 1$ and the first node $1+kn \times (i-1) \times i/2 + kn \times i$ of this circle.

Elements connection of the lower structure: The circular elements at the i -th circle ($ns+1 \leq i < nx$) and j -th ($1 \leq j \leq kn \times i - 1$) symmetric areas are generated by connecting the node $1+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko + j$ and the node $2+(i-ns-1) \times ko + kn \times (ns \times ns + ns)/2 + j$. Elements at the last symmetric areas of each circle are generated by connecting the node $2+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko$ and the node $1+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko + ko$ of this circle. Radial elements are generated by connecting the nodes of $ns+1$ circle and $ns+2$ circle. Elements at the i -th circle and j -th symmetric areas are generated by connecting the node $1+kn \times (ns \times ns + ns)/2 + j + (i-ns-1) \times ko$ and the node $1+kn \times (ns \times ns + ns)/2 + j + (i-ns) \times ko$.

Elements connection of the transition district: Connecting nodes of adjacent two laps only.

Kiewitt- Lamella Hybrid Dome(As show in Fig. 4)

Compared with Kiewitt-Ribbed hybrid dome, the difference lies in the lower part of the structure.

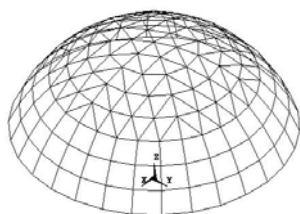


Fig.3. Kiewitt-Ribbed Dome

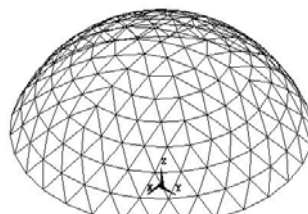


Fig.4. Kiewitt-Lamella Dome

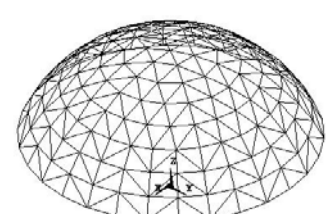


Fig.5. Kiewitt-Schwedler Dome

The lower structure nodal coordinates: The i -th ($ns+1 \leq i < nx$) odd circle and the j -th ($1 \leq$

$j \leq k_0$) symmetric area are: $x=R, y=(j-1) \times 360/k_0, z=90-i \times Dpha$. The node coordinates at the i -th even circle and the j -th symmetric area are $x=R, y=(j-1) \times 360/k_0 + 360/(k_0 \times 2), z=90-i \times Dpha$.

Elements connection of the lower structure: The dextral elements at the i -th ($ns+1 \leq i < nx$) circle and j -th ($1 \leq j \leq k_0$) symmetric areas are generated by connecting the node $1+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko + j$ and the node $1+kn \times (ns \times ns + ns)/2 + (i-ns) \times ko + j$. The levorotatory elements at the i -th ($ns+1 \leq i < nx$) odd circle and j -th symmetric areas are generated by connecting the node $1+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko + j$ and the node $2+kn \times (ns \times ns + ns)/2 + (i-ns) \times ko + j$, which at the i -th ($ns+1 \leq i < nx$) even circle and j -th symmetric areas are generated by connecting the node $1+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko + j + 1$ and the node $1+kn \times (ns \times ns + ns)/2 + (i-ns) \times ko + j$.

Elements connection of the transition district: Dextral element connection: the j -th ($1 \leq j < k_0$) symmetric areas are generated by connecting the node $1+kn \times (ns-1) \times ns/2 + (k-1) \times ns + i$ and the node $1+kn \times (ns+1) \times ns/2 + (k-1) \times (ns+1) + i$. The last symmetric areas ($j=k_0$) are generated by connecting the node $1+kn \times (ns-1) \times ns/2 + 1$ and the node $1+kn \times (ns+1) \times ns/2 + (k-1) \times (ns+1) + i$. Levorotatory element connection: the symmetric areas are generated by connecting the node $1+kn \times (ns-1) \times ns/2 + (k-1) \times ns + i$ and the node $1+kn \times (ns+1) \times ns/2 + (k-1) \times (ns+1) + i + 1$.

Kiewitt- Schwedler Hybrid Dome (As show in Fig. 5)

Compared with Kiewitt-Ribbed hybrid dome, Kiewitt- Schwedler hybrid dome has only diagonal rod. The diagonal rods at j -th symmetric areas between the i -th circle and $(i+1)$ -th circle are connected by the node $1+kn \times (ns \times ns + ns)/2 + j + (i-ns-1) \times ko$ and the node $2+kn \times (ns \times ns + ns)/2 + j + (i-ns) \times ko$. At the last symmetric areas, the diagonal rods are connected by the node $2+kn \times (ns \times ns + ns)/2 + (i-ns-1) \times ko$ and the node $3+kn \times (ns \times ns + ns)/2 + (i-ns) \times ko$.

Elements connection of the transition district: Radial element connection: It's the same as Kiewitt-Ribbed hybrid dome. Dextral element connection: the dextral rods are connected by the node $1+kn \times (ns-1) \times ns/2 + (k-1) \times ns + i$ and the node $1+kn \times (ns+1) \times ns/2 + (k-1) \times (ns+1) + i$ ($1 \leq k \leq kn, 1 \leq i \leq ns+1$). Levorotatory element connection: the symmetric areas are generated by connecting the node $1+kn \times (ns-1) \times ns/2 + (k-1) \times ns + i$ and the node $1+kn \times (ns+1) \times ns/2 + (k-1) \times (ns+1) + i + 1$.

Geodesic -Ribbed Hybrid Dome (As show in Fig. 6)

The transition region and the lower structure modeling process of the following three types are the same as the above three types, which will not be repeated here.

The upper nodes coordinates: The coordinates of apex are $(R, 0, 90)$. The node at the i -th circle and the j -th symmetric area is numbered as $1+kn \times (i-1) + j$, Its coordinates is $x=R, y=(j-1) \times 360/Kn, z=90-i \times Dpha$. The j -th ($1 \leq j \leq kn-1$) node at the i -th circle is numbered as $(ns \times kn) + (i \times i - 3 \times i + 2) \times kn/2 + 1 + (j-1) \times (i-1) + k$ ($1 \leq k \leq i-1$), and the last symmetric areas node of the i -th circle is numbered as $(ns \times kn) + (i \times i - 3 \times i + 2) \times Kn/2 + 1 + (kn-1) \times (i-1) + k$. Take sphere centre as origin to establish local coordinate system, and the XOY plane is set as the plane which decided by the origin, node $(i-1) \times kn + j + 1$ and node $(i-1) \times kn + j + 2$. These global angle of i -th circle elements are saved to the array $B(i)$. The j -th ($1 \leq j \leq kn-1$) node at the i -th circle is numbered as $(ns \times kn) + (i \times i - 3 \times i + 2) \times Kn/2 + 1 + (j-1) \times (i-1) + k$ and its coordinates are $(R, k \times B(i), 0)$. The last symmetric area is numbered as $(ns \times kn) + (i \times i - 3 \times i + 2) \times kn/2 + 1 + (kn-1) \times (i-1) + k$ and its coordinates are $(R, k \times B(i), 0)$.

Elements connection of the upper structure: The circular elements at the i -th circle and j -th ($1 \leq j \leq Kn-1$) symmetric areas are generated by connecting the node $1+kn \times (i-1) + j$ and $1+kn \times (i-1) + j + 1$. Elements at the last symmetric areas are generated by connecting the last node $1+i \times kn$ and the first node $1+i \times kn - kn + 1$ of this circle.

The elements connection of the transition district is the same as Kiewitt- Schwedler dome of Geodesic - Lamella dome (As show in Fig. 7) and Geodesic - Schwedler dome (As show in Fig. 8)

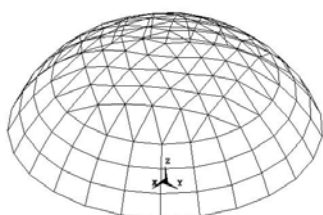


Fig.6. Geodesic-Ribbed Dome

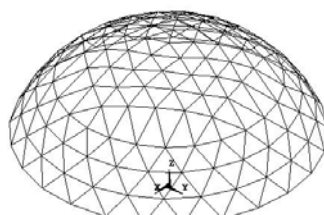


Fig.7. Geodesic-Lamella Dome

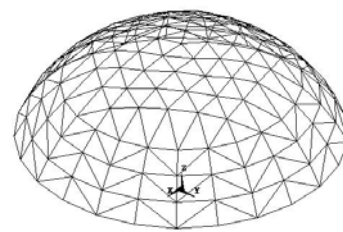


Fig.8. Geodesic-Schwedler Dome

Parametric Modeling Examples

Figure 9 to figure14 show six parameterized modeling examples of hybrid type single reticulated dome in different span S , rise high F , number of circle hoop symmetry areas kn , radial node cycles nx , and the upper structure laps ns , which is abbreviated to $(S-F-kn-nx-ns)$.

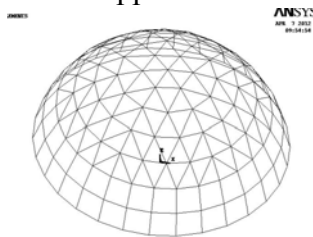


Fig.9. Kiewitt-Ribbed(30-12-6-7-5)

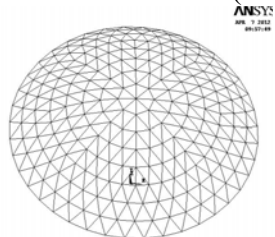


Fig.10. Kiewitt-Lamella(20-5-8-8-5)

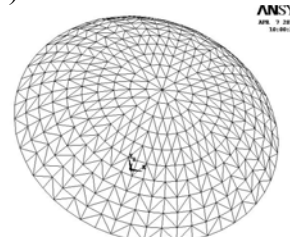


Fig.11. Kiewitt-Schwedler(35-10-10-10-5)

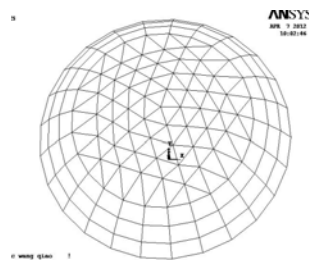


Fig.12. Geodesic-Ribbed(60-20-5-8-5)

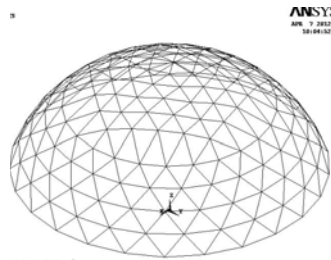


Fig.13. Geodesic-Lamella(70-25-5-9-5)

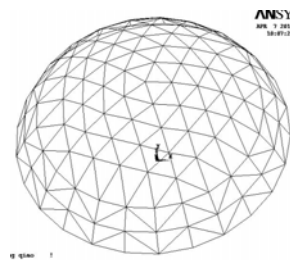


Fig.14. Geodesic-Schwedler(80-30-5-7-5)

Conclusions

A modeling method of the node generation and element connection of six hybrid single reticulated domes is established. The corresponding parametric modeling program is compiled by using APDL. Users can easily get the required parametric model just by inputting parameters such as the span S , rise high F , number of circle hoop symmetry areas kn , radial node cycles nx and the upper structure laps ns . The examples show that this method is simple, efficient and has important practical value. It provides a effective method to expand the reticulated dome type.

Acknowledgements

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