Study on the Walnut Mechanical Characteristics and Shucking Technology Based on Finite Element Analysis

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Abstract. In order to investigate the shucking technology and design the efficient Sheller, it's highly significant to study on the mechanical characteristics of walnut. The Pro/E software and finite element method was adopted to build the geometry and finite element model of walnut. Afterwards, the walnut stress distribution with different loads was analyzed to seek the optimum force-applying forms which usually produce the smaller deformation of walnut shell and more local crackles with better expansibility. The results show that the walnut shell can be shelled from the kernel easily when applied with the uniform and linear loads in the direction of shorter axis.

Keywords: Walnut, Shucking, Mechanical Characteristics, Finite Element Analysis

1 Introduction

Walnut is a kind of dried fruit with rich nutrition. If save with shell, it is easy to mildew. It is of great significance to shuck the walnut effectively. Because of the unreasonable force-applying forms, most peanut shellers used in domestic is of larger breaking rate, and can't meet the requirements of hulling rate, rate of whole and price-performance ratio[1,2].

Crack propagation is the basic condition of walnut shucking. In order to improve the shucking quality of shellers, it is important to apply a reasonable force on the walnut and make it crack easily. So it is necessary to analyze the force-applying forms and responses, and seek the optimum force-applying forms [3, 4].

The finite element method is an effective method to simulate the load conditions and compute the response. Nowadays, the method has been widely used for analyzing the mechanical characteristics of nut[5]. The Pro/E software and finite element method was adopted to build the geometry and finite element model of walnut. Afterwards, the walnut stress distribution with different loads was analyzed to seek the optimum force-applying forms which usually produce the smaller deformation of walnut shell and more local crackles with better expansibility. The results can provide references for the designment of walnut shellers.

2 Geometry size and mechanical characteristics of walnut

2.1 Geometry size

Take leatheroid walnut as the research subject, it behaves itself with irregular shape, so the model can be considered as an elliptic model in simulation. Take 20 grains of walnut into consideration, the geometry sizes are computed in the method of statistical analysis. The geometry sizes in the three direction of XYZ are described as follows: 27 mm, 25 mm and 30 mm. Additionally, the average thickness and mean value of the gap between walnut shell and kernel are 1mm and 0.2 mm respectively.

2.2 Mechanical characteristics

The shell and kernel of walnut belong to two different kinds of material, and the stiffness of shell is greater than that of the kernel. So their elastic modulus is inevitability different from each other. Additionally, the materials of shell and kernel can be regarded as isotropic materials, that is to say the horizontal elastic modulus of materials are equivalent to the longitudinal and tangential elastic modulus. Refer to the wood and other nuts, and the elastic modulus of walnut shell is taken as 10 Mpa, which is ten times of that of walnut and kernel. The Poisson Ratio is 0.3[5, 6].

3 Finite element model of walnut

3.1 Geometry model

The structure of walnut is symmetric, so the 1/2 symmetric model can be used for simulation. Fig.1 shows the 1/2 solid model of walnut built by the Pro/E software. When the model is converted to the IGES files, it can be imported to the software of ANSYS for finite element analysis.

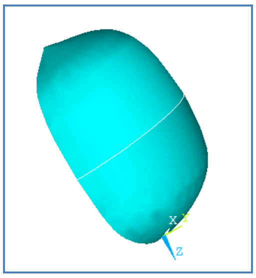


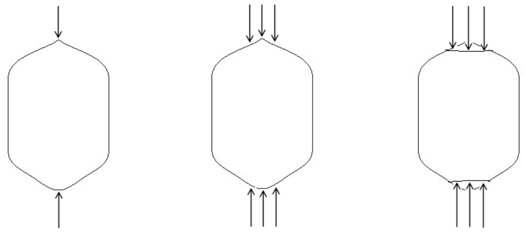
Fig.1 Half model of walnut

3.2 Element type selection and division

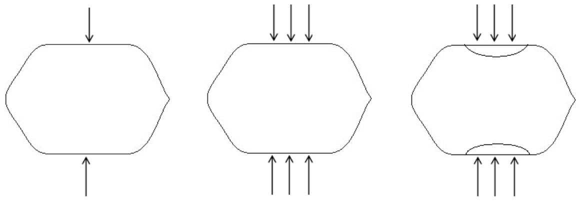
Walnut consists of two parts, shell and kernel. In order to simplify the computation, the materials of shell and kernel can be regarded as linear elastic and isotropic materials. Furthermore, in the process of element type selection, the element type of walnut shell is defined as Shell 93, while the kernel is defined as Solid 95.In addition, the inner surface of walnut shell and the outer surface of walnut kernel makes for a contact. In order to simulate the interaction between the walnut shell and kernel, the contact element was introduced into the finite element model of walnut. The inner surface of walnut shell is defined as the target surface, while the outer surface of walnut kernel is defined as the contact surface. When using the contact-creating guide to create the contact, the software system can automatically generate the target element of Targe170 and contact element of Conta 174.Since the walnut model is relatively simple, the automatic meshing tool was adopted to mesh the walnut shell and kernel.

3.3 Definition of load and constraint

In order to seek the optimum force-applying forms for shell shucking, the stress and strain distribution with six different loads was investigated by simulation. The loading forms can be described as follows :(1) applied with the concentrated load in the long axis (Fig. 2 (a)), and the constraint with zero displacement is applied to the bottom of walnut; (2) applied with the uniform and linear load in the long axis (Fig. 2 (b)), and the constraint with zero displacement is applied to the bottom of walnut; (3) applied with the uniform surface load in the long axis (Fig. 2 (c)), and the constraint with zero displacement is applied to the bottom of walnut;(4) applied with the concentrated load in the short axis (Fig. 2 (d)), and the constraint with zero displacement is applied to the opposite key nodes of walnut; (5) applied with the uniform and linear load in the short axis (Fig. 2 (e)), and the constraint with zero displacement is applied to the opposite key nodes of walnut; (6) applied with the uniform surface load in the short axis (Fig. 2 (f)), and the constraint with zero displacement is applied to the opposite key nodes of walnut.



(a) (b) (c)



(d) (e) (f)

Fig. 2 Loading forms of walnut

4 Finite element analysis of walnut

4.1 Stress and strain analysis of walnut applied with the concentrated load in the long axis

Fig.3 shows the finite element model of walnut applied with the concentrated load in the long axis. The load is 700 N. Fig.4 shows the Z-Component of displacement, which is also known as the deformation in the loading direction. As shown in the figure, the largest deformation is located at the loading point, and the deformation area looks like a semicircle about the loading point. Fig.5 and Fig.6 shows the equivalent stress and strain distribution of walnut respectively. It can be seen that the largest stress and strain is located at the loading point. The stress and strain spreads from the point out to the periphery, and decreases gradually.

According to the above analysis, we can predict that the stress and strain distribution of walnut behaves itself with no definite direction. The walnut cracks from the loading point out to the periphery, which usually brings about the local fracture, and works against the shell shucking of walnut.

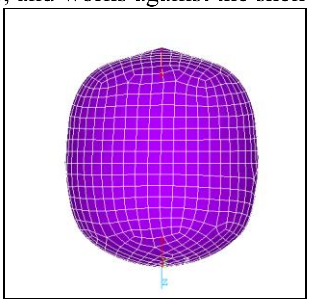


Fig.3 Finite element model of walnut

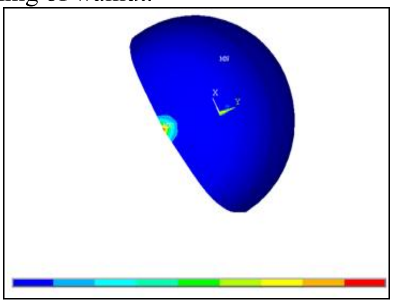


Fig.4 Z-Component of displacement

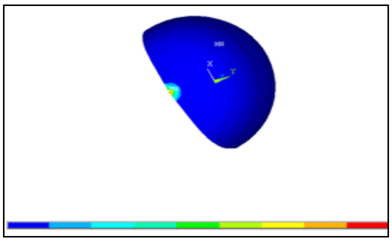


Fig.5 Von Mises stress graph of walnut

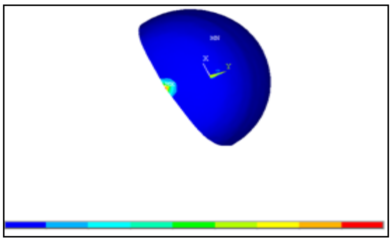


Fig.6 Von Mises strain graph of walnut

4.2 Stress and strain analysis of walnut applied with the uniform and linear load in the long axis

Select the upper endpoint of the long axis as the central point of the loading curve, and apply the uniform and linear load to the loading curve in the positive direction of Z axis. The total length of loading curve is 2mm, and the uniform load is 350N/mm.

Fig.7 shows the Z-Component of displacement when walnut is applied with the uniform and linear load in the long axis. As shown in the figure, the largest deformation is located in the loading curve, and the neighboring areas are the next. In other words, outward from the loading curve, the deformation decreases gradually.

Fig.8 and Fig.9 shows the equivalent stress and strain distribution of walnut respectively. Obviously, the distribution of equivalent stress is similar to that of walnut strain, and the distribution area looks like a semi ellipse. The direction of longer axis is consistent with the loading direction, and the maximum stress and strain is located in the loading curve, and the neighboring areas are the next.

On the basis of this, it can be concluded that the stress and strain distribution of walnut behaves itself with definite direction. The walnut should crack from the loading curve out to its sideways. However, since the distribution areas of walnut stress and strain are larger, the rupture rates can meets the corresponding requirements, but a great deal of broken kernels are caused meanwhile.

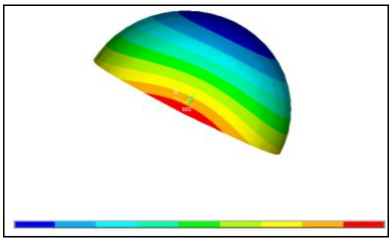


Fig.7 Z-Component of displacement

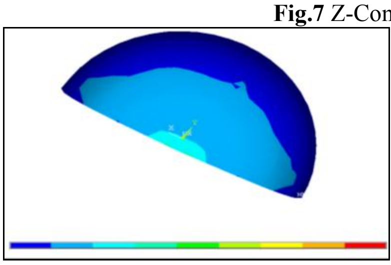


Fig.8 Von Mises stress graph of walnut

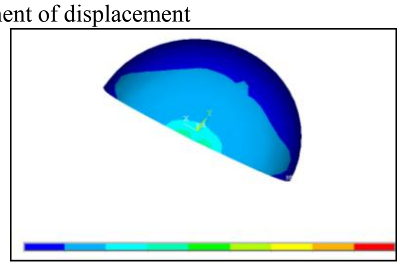


Fig.9 Von Mises strain graph of walnut

4.3 Stress and strain analysis of walnut applied with the uniform surface load in the long axis

Select the upper endpoint of the long axis as the central loading point, and apply the uniform surface load to the loading surface in the positive direction of Z axis. The total area of loading surface is 10 mm^2, and the uniform load is 70N/ mm^2.Fig.10 shows the Z-Component of displacement when walnut is applied with the uniform surface load in the long axis. As shown in the figure, the maximum and minimum deformations are located on the two sides of walnut respectively.

Fig.11 and Fig.12 shows the equivalent stress and strain distribution of walnut respectively. It is clear that the stress distribution is similar to that of walnut strain, and the greater stress and strain is mainly concentrated in the loading area. The stress and strain almost remains unchanged in the loading area.

According to the above analysis result, it can be speculated that the crack of walnut is lack of directionality and the loading area cracks first. Compared with the first two conditions, the rupture zone is much larger, and meets the requirements of the rupture rate. Being lack of definite directionality, the stress of the two sides usually produces lots of broken kernels.

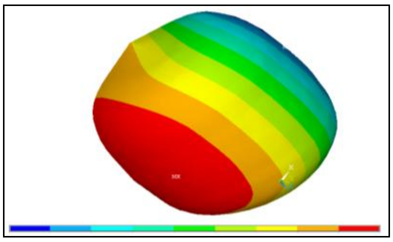


Fig.10 Z-Component of displacement

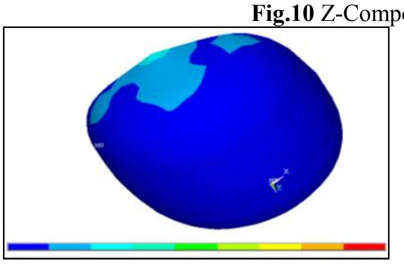


Fig.11 Von Mises stress graph of walnut

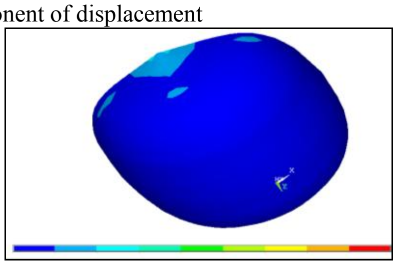


Fig.12 Von Mises strain graph of walnut

4.4 Stress and strain analysis of walnut applied with the concentrated load in the short axis

Select the endpoint of the short axis as the central loading point, and apply the concentrated load of 300N to the loading point in the negative direction of Y axis. Fig.13 shows the Y-Component of displacement, which is also known as the deformation in the loading direction. As shown in the figure, the largest deformation is located at the loading point, and the deformation area looks like a circle about the loading point.

Fig.14 and Fig.15 shows the equivalent stress and strain distribution of walnut respectively. It can be seen that the stress and strain distribution is similar to that of Y-Component displacement, and lack of definite directionality. The distribution area just looks like a circle about the loading point and the maximum stress and strain is just located at the loading point.

Since the stress and strain distribution of walnut behaves itself with no definite direction, it can be concluded that the walnut cracks from the loading point out to the periphery, which usually brings about the local fracture, and is not useful for the shell shucking of walnut.

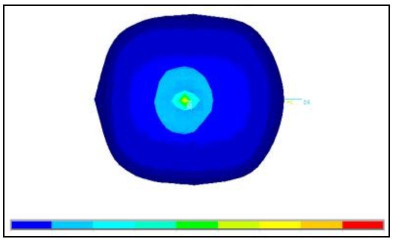


Fig.13 Y-Component of displacement

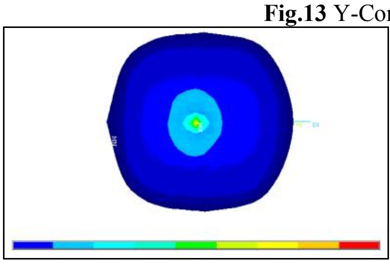


Fig.14 Von Mises stress graph of walnut

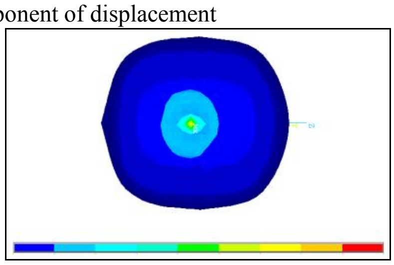


Fig.15 Von Mises strain graph of walnut

4.5 Stress and strain analysis of walnut applied with the uniform and linear load in the short axis

Select the endpoint of the short axis as the central loading point and apply the uniform and linear load to the loading curve in the negative direction of Y axis. The total length of loading curve is 2mm, and the uniform load is 150N/mm.

Fig.16 shows the Y-Component of displacement when walnut is applied with the uniform and linear load in the short axis. As shown in the figure, the largest deformation is located in the loading curve and outward from the loading curve, the deformation decreases gradually.

Fig.17 and Fig.18 shows the equivalent stress and strain distribution of walnut respectively. Obviously, the distribution of equivalent stress is similar to that of walnut strain, which shows definite directionality. Furthermore, the distribution area can be regarded as ellipse, whose direction in the long axis is in accordance with the direction of load distribution. The maximum stress and strain is located in the loading curve, and the neighboring areas are the next. That is to say, the stress and strain decreases gradually from the loading curve to the sideways.

Since the stress and strain distribution of walnut behaves itself with definite direction, the walnut should crack from the loading curve out to its sideways, and the crack is highly expandable. Therefore, this kind of loading form is suitable for shell shucking.

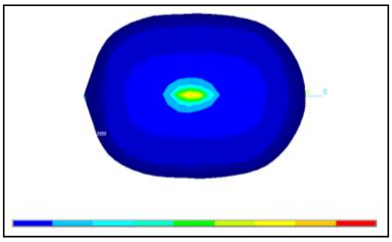


Fig.16 Y-Component of displacement

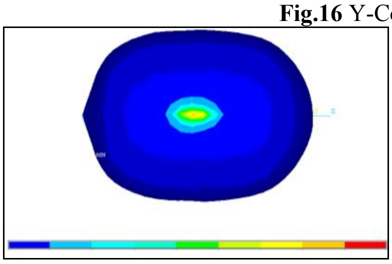


Fig.17 Von Mises stress graph of walnut

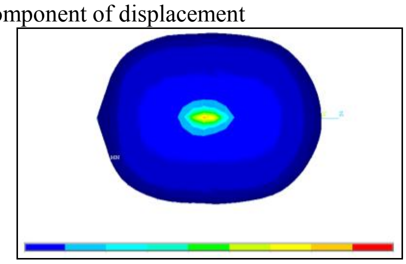


Fig.18 Von Mises strain graph of walnut

4.6 Stress and strain analysis of walnut applied with the uniform surface load in the short axis

Select the endpoint of the short axis as the central loading point, and apply the uniform surface load to the loading surface in the negative direction of Y axis. The total area of loading surface is 10 mm^2, and the uniform load is 30N/ mm^2.

Fig.19 shows the Y-Component of displacement when walnut is applied with the uniform surface load in the short axis. As shown in the figure, the deformation area is similar to the loading area, but much larger that the latter.

Fig.20 shows the equivalent stress of walnut. It can be seen that the greater stress is mainly concentrated in the loading area, much smaller stress is also scattered in the other areas.

Fig.21 shows the equivalent strain distribution of walnut. Compared with the equivalent stress, the distribution area of greater strain is relatively small. The greater strain is mainly concentrated in the loading area.

On the basis of this, it can be speculated that the crack forms of walnut under this condition is similar to that of the condition with concentrated load, and lack of definite directionality. Because the rupture zone is much larger, this loading form meets the rupture requirements. However, it produces lots of broken kernels at the same time, and works against the shell shucking of walnut.

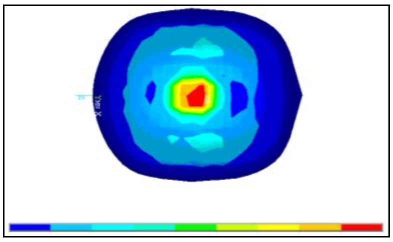


Fig.19 Y-Component of displacement

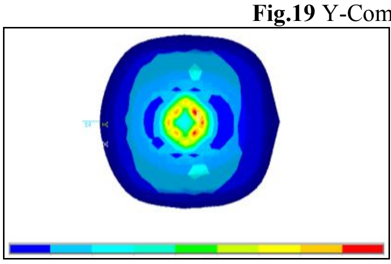


Fig.20 Von Mises stress graph of walnut

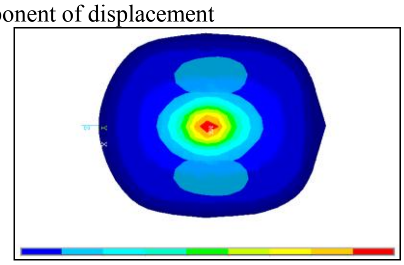


Fig.21 Von Mises strain graph of walnut

5 Conclusions

The Pro/E software and finite element method was adopted to build the geometry and finite element model of walnut. On the base of this, the stress and strain distribution with six different loads was investigated by simulation. The conclusions can be described as follows:

(1)When applied with the concentrated and uniform surface load in the long axis, the stress and strain distribution of walnut behaves itself with no definite direction, the walnut cracks from the loading point out to the periphery, which usually brings about the local fracture, and works against the shell shucking of walnut; when applied with the uniform and linear load in the long axis, the stress and strain distribution of walnut shows definite directionality, and the walnut cracks from the loading curve out to its sideways. The larger distribution areas usually bring about lots of broken kernels.

(2) When applied with the concentrated and uniform surface in the short axis, the stress and strain distribution of walnut is lack of definite directionality, the walnut cracks from the loading point out to the periphery, which usually brings about the local fracture, and works against the shell shucking of walnut; when applied with the uniform and linear load in the short axis, the walnut cracks from the loading curve out to its sideways, and the crack is highly expandable. This kind of loading form is very suitable for shell shucking.

(3) It is the most suitable loading mode for walnut shell shucking to impose the uniform and linear load on the short axis.

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Biography

Hongmei Xu received the B.S and M.S degree from Huazhong Agriculture University, and the Ph.D. degree from Zhejiang University, in 2001, 2004, and 2008, respectively. She is currently the lecturer of the Department of Engineering and Technology at Huazhong Agricultural University. Her primary professional interests lie in digital simulation and analysis of the NVH performance for automobiles, modern signal process, and agricultural product processing technology.