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A Review on Fracture Characteristics of Walnut

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Abstract

Walnut as a typical agricultural material, its fracture characteristics always affect its primary processing quality, and the study of walnut fracture characteristics also provides theoretical reference for other nuts. Therefore, a large number of domestic and foreign scholars put forward a series of research methods for walnut brittle shell materials. The test methods, mechanical models and influencing factors of walnut fracture parameters were summarized by combing the experimental studies on walnut fracture characteristics by domestic and foreign scholars. On this basis, the development law and research prospect of walnut fracture characteristics were prospected, hoping to lay a foundation for the future research of this kind of problems.

Keywords

Walnut; Brittle Material; Fracture Properties.

1. Introduction

Walnut is an important economic, oil and ecological tree species in the world[1].They are widely grown in many parts of the Americas, Europe and Asia, and together with almonds, cashews and hazelnuts are known as one of the four main dried fruits. Walnut is rich in a variety of nutrients such as fatty acids, protein, dietary fiber and rich trace elements such as calcium, magnesium, zinc, etc., is an important dietary supplement food. Regular consumption can improve anti-aging, prevent cell aging, and reduce cholesterol level and triglyceride concentration, which is of great help to alleviate malnutrition and reduce the risk of cardiovascular and cerebrovascular diseases. In addition, walnuts have a unique edible flavor. Therefore, the cultivation area of walnut in China is increasing year by year. Currently, the planting area is about 1.3 million km, and the annual output of 979,400 tons is the first in the world. With the increase of walnut yield year by year, its economic benefits are more and more considerable. In order to ensure the healthy and stable development of walnut industry, local governments have stepped up the introduction of corresponding policies and provided financial support. In particular, the Xinjiang government has issued several documents such as "Opinions on Further Accelerating the Development of Characteristic Forestry and Fruit Industry" and provided special financial support for the development of forestry and fruit industry, among which walnut industry is one of the key points. In Xinjiang, walnut planting in Kashgar, Hetian, Aksu and other southern Xinjiang region, the annual output of 837,000 tons jumped to the second national. Walnut industry is ushering in golden development period.

At present, the walnut industry mainly takes direct sales and primary and deep processing (walnut oil, walnut powder, walnut beverage, jujube walnut, etc.) as the main sales form. With the continuous improvement of the quality of life, the public demand for walnut is no longer just direct consumption, but diversified demand. In order to meet the public demand for various walnut products, but also to increase the walnut industry chain and value chain, so it is necessary to pay attention to each link of walnut initial and deep processing, in order to ensure the quality and efficiency of processing. It is worth noting that in the whole process of walnut processing is the basis of the follow-up work, its

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processing effect directly determines the product quality and economic value of walnut later. In addition, with the increase of walnut output year by year, the primary processing of walnut has brought unprecedented pressure. Walnut primary processing refers to the use of a variety of processing equipment to achieve complete walnut into walnut kernel process, the process is completed by drying, transportation, grading, breaking the shell, shell kernel separation and a series of procedures. It is constantly affected by various loads in the whole processing process, such as extrusion and collision between processing equipment and walnuts, walnuts and walnuts, so that the mechanical properties of walnuts have obvious changes. These changes will bring various effects on the primary machining process. For example, walnuts are essential for transportation and grading. The cracking of the nut shell is easy to cause pollution, moth, oxidation, etc., so it is necessary to prevent the occurrence of cracking. However, in the cracking process of walnut shell, it is necessary to ensure the integrity of the kernel to make the walnut shell fracture more easily, and the length of crack propagation is longer. In addition, in the separation process of walnut shell kernel, according to the different separation forms, the beneficial fracture products are also different. In conclusion, the changes of mechanical properties in the process of primary machining directly affect the quality of primary machining, especially the fracture characteristics of walnut have a significant impact on the effect of primary machining. Therefore, the study on the fracture characteristics of walnut can help improve the quality of primary machining and has important engineering significance.

Since the 1990s, China has carried out research on the physical and mechanical properties of chestnuts, walnuts, apricot pits, pine nuts, macadamia nuts and other nuts. Among them, the compressive fracture characteristics of nuts are the most concerned by predecessors, because the initial purpose of the research on the physical and mechanical properties of nuts is to clarify the fracture characteristics of nuts themselves. It provides theoretical support for the design and parameter selection of the machine. In order to achieve the mechanization of nut breaking kernel, improve work efficiency. With the further development of research, there are also different demands for nut fracture characteristics in primary processing. For example, extrusion fracture is the main form of macadamia nut breaking machinery, and there are extrusion, impact and other fracture forms in walnut processing. Therefore, it is necessary to conduct in-depth study on the fracture characteristics of plate and shell materials, such as fracture characteristics under different loading forms. Walnut is a typical plate and shell material, and the study of its fracture characteristics under different loading forms can provide theoretical support for the fracture mechanism of nuts, so it has important scientific significance.

2. Study on Compression Fracture Characteristics

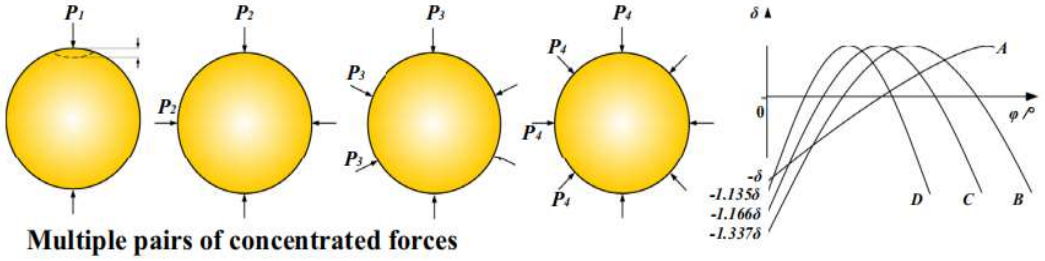

Fig.1 Extrusion type walnut shell force diagram

Domestic and foreign theories on walnut extrusion fracture characteristics focus on the stress distribution of thin shell under stress, fracture toughness of shell, critical load of shell material, finite element analysis of shell fracture and so on.For example, Wu Ziyue[2] first measured the thickness, size and sphericity of walnut shell, and then simplified it into isotropic uniform thickness of the thin shell, using the thin shell theory for internal force and displacement analysis see Fig. 1.The results

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show that the effect of two pairs of normal concentrated forces is better for the complete uniform rupture of the shell.

Zhao Z P[3] used the thin shell theory and the linear superposition method to calculate the effect of concentrated force on the displacement and compression deformation of walnut. The results showed that the two pairs of concentrated force produced the largest displacement under the same load.In addition, The results show that the propagation of wood crack along the grain accords with LEFM. The fracture toughness along the grain is an inherent property of wood.It can be seen that through the elaboration and application of various theories, theoretical research on fracture characteristics of wood thin shell materials has made some progress. Due to the complexity and diversity of the actual situation, the theoretical calculation results are different from the actual situation. Therefore, the combination of theory and nut characteristics becomes the key and focus of research.The initial attempt was first made on macadamia nuts. Wang cut macadamia nuts into standard C-shaped rings and conducted compression fracture tests. The results showed that macadamia nuts were brittle fracture and its tensile strength was less than the compressive strength see Fig. 2.

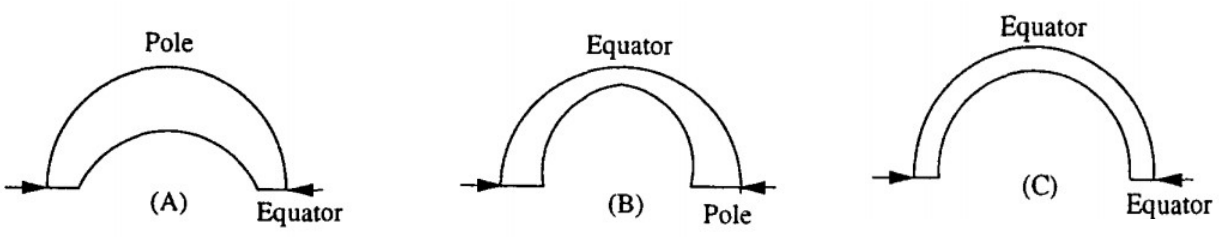

Fig.2 Geometry of C-ring specimens.

Based on previous studies, Wang[4] analyzed the whole Macadamia nut under the compression of rigid plate and calculated the stress distribution and the corresponding strength factor by using thin shell theory and box contact theory, thus solving the nut fracture determination problem.It provides new theoretical support for better prediction of nut fracture. However, different nut structures may have different fracture characteristics. For example, the fracture of walnut needs to take into account the difference between loading positions.Sharifian et al. determined the difference caused by walnut compression position through uniaxial compression test.Shi Jixin, He Y C, Zhou J[5] et al., through finite element analysis, found that the axial load along walnut was conducive to crack propagation after fracture. And found out the best way of applying force,see Fig. 3.

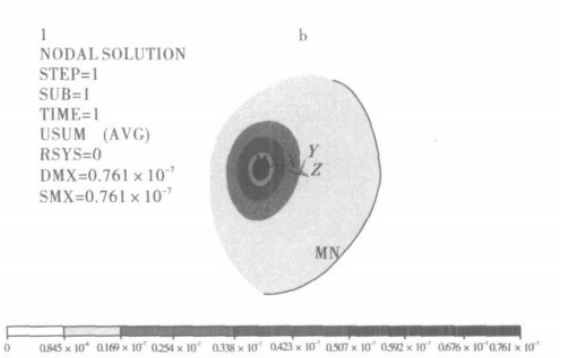

Fig.3 Equivalent stress and demometion cloud atlas of Z direction forced in YZ plane

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The above theoretical research lays a theoretical foundation for the development of this study. However, based on the above theories, it can be seen that most theoretical analyses are based on the assumption that walnuts are approximately isotropic ellipsoid, and the fracture characteristics of walnuts are analyzed based on the thin shell theory and box contact theory. However, considering the special structure and uneven medium of walnut in the future, the mechanism of walnut fracture is not clear.Especially walnut stress distribution calculation, its irregular shape and special structure, so that theoretical research and experimental research always exist such a difference. Therefore, it is still limited to clarify the fracture mechanism of walnut only by using the fracture theory of walnut.

The experimental study on extrusion fracture characteristics of walnut was carried out from two aspects. The first aspect was the influence of external factors, such as loading rate, loading mode, loading direction and pretreatment mode, on fracture characteristics.Likui etc. Using the quasi static compression experiment on the factors affecting the size of a walnut shell force was studied, and the extrusion direction, loading rate, pretreatment etc factors, which affect the breaking force of size were assessed, obtained the best egg extrusion direction, loading rate and the dimension of walnut and breaking strength of the relationship, for pretreatment can decrease the breaking strength of the walnut shell ago, It provides a reference for the structural design of walnut breaking machine.What needs special attention is the second aspect of internal factors. Such as size, water content, varieties and other factors on the impact of extrusion fracture characteristics. Shen L Y, Liu M Z, Man Xi L[6] [7]et al. studied the influence of internal factors such as size and water content on walnut fracture characteristics, and the results showed that the larger the size, the larger the fracture energy required, and the larger the water content, the larger the deformation required for walnut fracture. There were significant differences in fracture characteristics among different varieties.In addition, it is worth noting that Zhang H[8] et al observed the fracture morphology of Wen185 walnut shell by scanning electron microscope (SEM), and found that the fracture of walnut shell was divided into three regions: loose zone, dense zone and transition zone. It was judged that walnut shell fracture was characterized by brittle fracture of outer layer and ductile fracture of inner layer, and mixed fracture in the area connected with inner and outer layer, presenting brittle fracture characteristics in macro.

2.1 Conclusion

To sum up, for the experimental study of walnut fracture characteristics, domestic and foreign scholars focus on the influence of internal factors (such as size, water content, etc.) and external factors (such as pressure head form, loading direction, etc.) on walnut fracture characteristics (such as fracture energy, fracture force, etc.).Although research progress is obvious, but with the effect of fracture prediction, the possible reason is that, because of the discussion is obviously neglected an important factors in walnut since the survival in the fracture, the influence of initial crack on existing research shows that the influence of initial crack on fracture is significant, therefore, to study the influence law of initial crack on fracture appear very necessary.

3. Research Status of Impact Fracture Characteristics of Walnut at Home and Abroad

Previous studies have shown that impact dynamics is different from statics[9], and generally two basic effects should be included, namely inertia effect and strain rate effect. The former leads to the study of various forms of wave propagation properties, while the latter is the study of various types of strain-rate dependent rate-type constitutive relations and failure criteria. Blind use of statics will lead to misunderstanding of material dynamic constitutive relations.The study on deformation fracture of spherical shells began in the 1960s. Leckie[10] et al. used rigid punches to load in the center of refined hemispherical shells and completed a series of relevant experimental studies. In recent years, with the advancement of science and technology, it is possible to conduct dynamic experiments and sampling. Cupta N K[11] et al. tested the aluminum spherical shell and conducted systematic experimental research and theoretical analysis on the crushing mechanism and energy absorption capacity of the aluminum spherical shell under the dynamic impact of mass blocks. Yu

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Tongxi[12] et al. from Hong Kong University of Science and Technology in China chose ping-pong as the experimental object and conducted experiments on a single ball under various loading conditions. Meanwhile, finite element simulation and theoretical analytical model were used to analyze the fracture characteristics of materials. Ning J G, Mu J[13] et al. studied the dynamic process of large deformation of spherical thin shells under bullet impact. The influence of impact velocity on large deformation of plastic spherical shell is analyzed. However, the development of fracture or crack caused by low energy impact is not considered. The results show that the impact of low energy on fracture is significant. Analysis of fracture characteristics from the perspective of energy is widely used in rock fracture research. Rock deformation and failure is a process in which incident energy is transferred inside rock and transformed into internal energy and kinetic energy. Based on rock impact damage and acoustic wave test experiments, Gao W X et al. studied the relationship between rock dynamic damage and its evolution law and ultrasonic attenuation, and established a model to describe rock impact compression and tensile damage based on the principle of damage energy dissipation. Based on the brittle dynamic fracture criterion, Li X B[14] et al. analyzed the energy dissipation differences of rock under three different loading wave properties, namely rectangular wave, bell-like wave and exponential attenuation wave, through formula derivation and theoretical research. Xie H P[15] et al. studied the process of rock deformation and failure from the perspective of energy. Through theoretical and experimental studies, it is concluded that stress-strain strength cannot well describe the characteristics of rock failure, while energy plays a fundamental role in rock deformation and failure, and rock fracture is a typical process of energy release.With the deepening of the research on impact fracture, Chen Qing S et al. divided fracture into three modes: crack generation, moderate failure and intense fracture. Hong L[16] et al. studied the deformation and energy characteristics of rock, analyzed the energy transformation law in the process of rock damage and failure, and quantitatively analyzed the fatigue failure threshold of rock from the perspective of energy loss.

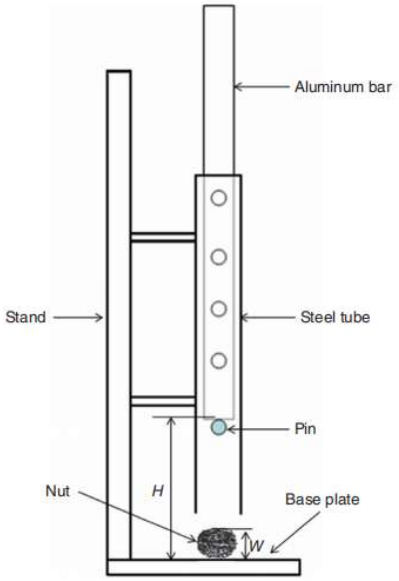

Fig.4 Schematic diagram of the impact test apparatus

To sum up, for the study of impact fracture, most of the research hotspots of scholars at home and abroad focus on the resistance of materials to energy and the determination of fracture. The results show that the study of material fracture from the perspective of energy can combine theory with experiment and obtain good research results.Although the influence of impact load on fracture characteristics has been studied very deeply. However, walnut, as a typical brittle material with

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spherical shells, has not been combined with the existing studies on the fracture characteristics under impact load.

Feizollah[17] et al.conducted a single impact on walnuts using a drop hammer impact tester and found that the probability of walnut fracture increased with the increase in impact energy,see fig.4.

Wang X X et al. designed and developed a centrifugal walnut shell breaker. Its design principle is that the walnut is given a certain initial speed through the rotating mechanism, and the walnut impacts the baffle with the speed, and the impact energy causes the walnut to break under the reaction of the baffle. The greater the impact energy, the better the effect. Gao J[18] et al. designed the striking walnut shell breaker. He Y C[19] designed the pneumatic percussion walnut shell breaking machine for walnut shell breaking and kernel extraction.In summary, previous effective results only focused on whether walnut fracture occurred after impact and impact, and the distribution of walnut fragments after fracture, but failed to reveal walnut fracture characteristics and fracture mechanism. Therefore, the mechanism of impact fracture of walnut needs further study, especially the criterion of walnut initiation, which can lay a foundation for the revelation of walnut fracture mechanism.

4. Summary and Prospect

This paper introduces the theoretical and experimental research on the fracture characteristics of walnut under extrusion and impact fracture, and analyzes them according to their own characteristics. Based on the domestic and foreign literature and criterion for evaluating the fracture characteristics of walnut, the calculation formula of fracture energy/fracture force and the evaluation method of fracture properties were introduced in detail.

The main influencing factors of nut fracture parameters were summarized according to the domestic and foreign research literature of walnut.

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