Simulation Analysis of Material Compression Performance in Biomass Molding Machine

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Abstract

The vertical annular molding machine is a new type of biomass fuel pellet producing equipment, with the use of eccentric shaft roller structure, the roller roll around the shaft, and the annular mold contacts with and extrude straw stalk powder material. Base on virtual simulation technology, the compression molding process of straw stalk powder is analyzed by finite element analysis (FEA) software, we can understand the plastic deformation and the stress distribution during the forming process of straw stalk particles, optimize the annular mold structure of the equipment, and ultimately improve the quality of products.

Keywords

Vertical Annular Molding Machine, Straw Stalk, Compression Molding.

1. Introduction

Straw stalk fuel is regarded as a renewable energy source, and the vertical annular molding machine is a new type of equipment for the production of straw stalk fuel. In the process of production, the load of vertical annular molding machine is complicated , it is always found that there are some cracks on the surface of the finished products of straw stalk pellet, which affect the quality of the products.

2. Theoretical model

First, we introduce the fundamental principle of the machine. When the molding machine works, the motor drives the main shaft in order to drive the roller to rotate around the spindle, the relative motion between the roller and annular mold that fixed on outer layer of the machine occurs. With the revolution and rotation of the roller, biomass raw materials flowing into the space between the roller and annular mold are pressed into the forming hole of annular mold, after experiencing position rearranging, plastic deformation and elastic deformation etc. complex course [1], powders are extruded from the hole of annular mold, and shaped into rod-like products. According to the process of wood particle molding, it can be divided into three zones: [2]: bulk material zone, deformation compression zone and extrusion processing zone. The forming process is shown in Figure 1.

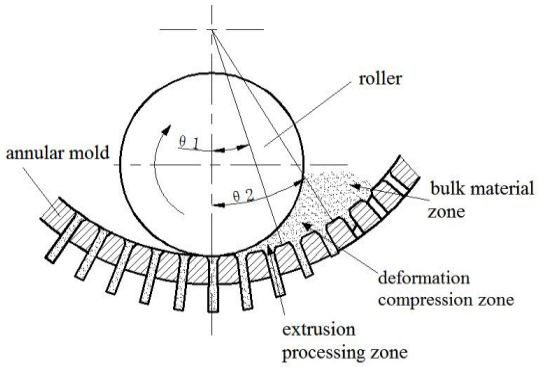

Fig.1 schematic diagram of the compression molding process

First, raw material powders are poured into the bulk material zone, rolled with the rotation of roller then pushed into deformation compression zone and extrusion processing zone. In the process of deforming , the raw material powders are subjected to heat and force, the situation is very complicated, we selects the extrusion process as the main research object in this chapter. The principles of establishing the model are as follows:

(1) During the extrusion stage,straw stalk powders are under the action of force and heat, lignin among the powders enter the molten situation,particles stick together, the deformation process can be regarded as a deformation of aggregate, which can be viewed as a continuous medium.

(2) According to the structural characteristics, it is converted to two-dimensional model, and the extrusion process is symmetrical, in order to speed up the calculation speed, only half of the symmetrical axis shall be studied. Diagram of model building is shown in figure 2.

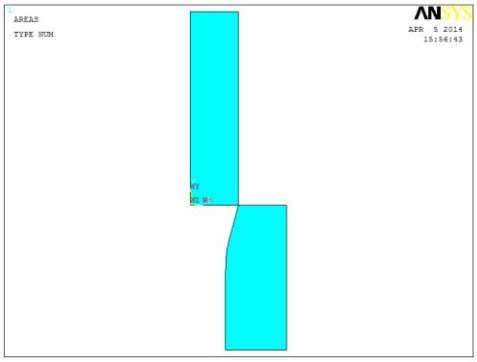

Fig.2 Model building

3. Finite element analysis of straw stalk compression molding

Taking maize stalk pellet as the research object, during the compression molding process, there are frictions between stalk and mold, and in the process of research, it is necessary to analyze the force of the mold, so the establishment of two kinds of material models is necessary. Material properties [3-4] are shown in table 1:

Tab.1 Material properties

material	property	value
maize stalk	density (kg/m^3)	330
	Poisson ratio	0.38
	Compression modulus /GPa	8
	Cohesion /KPa	28.67
	internal friction angle / °	32.76

mould	Poisson ratio	0.28
	Elastic modulus GPa	210

Taking into account the plasticity and large deformation of the stalk compression, the PLANE82 of 2-D, 8 node element is selected. Meshes are divided as shown in figure 3.

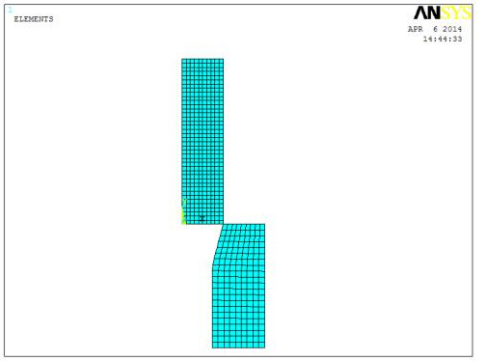

Fig.3 Model finite element meshes

During the process of stalk powder molding, there are friction and extrusion phenomenon between mold and stalk powder, so the analysis will establish contact between mold surface and outside of stalk, the mold is regarded as the rigid target surface, stalk is regarded as a flexible body surface, define the contact element and target element during the mutual extrusion process between stalk powder and mold are Conta172 and Targe169, the type of contact is Surface to Surface. Schematic diagram of contact is shown in figure 4.

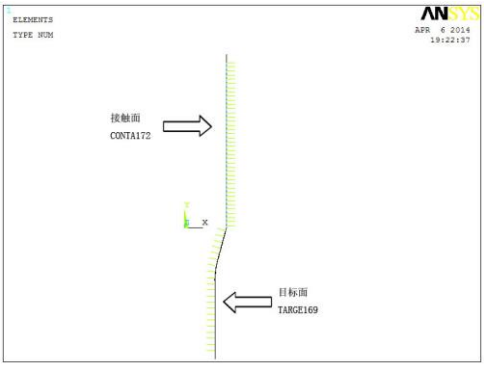

Fig.4 Chart of contact pair model

The compression molding process of maize stalk powder is affected by temperature, pressure and water content, the Y axial vertical downward displacement is used as the load on the stalk powder. In order to simplify the operation of the computer, the model is simplified into the 1/2 axis symmetric model for load and constraint applied. The constraint of X axis is applied to the center line of powder, full constraints is applied to the bottom and the right surface of mold. The constraint and load distribution are shown in figure 5.

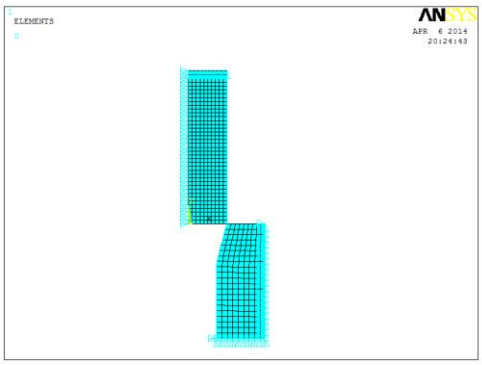

Fig.5 Chart of restriction and load distribution

Define analysis type (New Analysis) as static analysis (Static). Because large deformation will be produced during the process of stalk compression molding, we need to set Large displacement in the 'Sol' n control option, then open the linear search, it will be helpful for the smooth calculation.

4. Simulation results analysis

Figure 6 reflects the flow deformation of stalk powder during compression. It can be seen through cloud diagram that in the molding process, due to axisymmetric extrusion, the flow of stalk is more balanced, the cloud diagram reflects the radial flow of material extruded by the mold [5-6].

From the cloud diagram we can observe that obvious changes occurs in the meshes of X, Y axis direction, and the closer to the mold , the more obvious the deformation phenomenon is, the lag phenomenon occurred in the near vicinity of mold . This is because during the extrusion process, pressure exist between stalk powder and the mold and consequentially produce friction, that results in the slight lag of contact zone behind the middle zone. With the extrusion process continued, the deformation of the middle zone become stable, and the deformation of contact zone became steady.

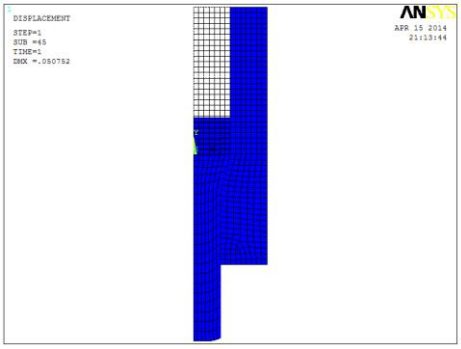

Fig.6 Flow chart of the straw in compressing process（50%）

Figure 7 is the friction stress cloud diagram of the contact surface on which friction is produced between the straw stalk material and the mold during the extrusion and compression process. From the cloud diagram analysis, we draw the conclusion that the zone with the maximum friction is tapered hole zone in the process that stalk powders are compressed, there is a maximum friction in the lower place of tapered hole in the middle part of the mold. Mold is easily worn in this position.

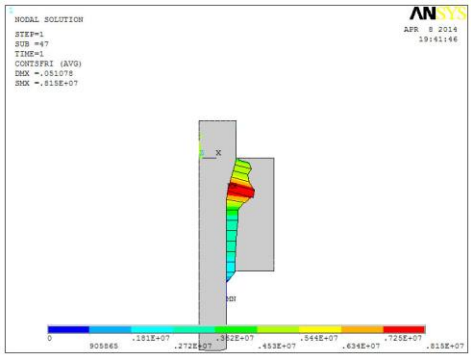

Fig.7 Friction stress chart of the straw in compressing process

Figure 8 is the shear stress cloud diagram of straw stalk powder in the extrusion and compression process. Through the cloud diagram analysis we draw the conclusion that during the compression process, straw stalk pellets are subjected to the shear stress and large deformation happens. This deformation mainly takes place in the position of tapered contact zone of mold. With the straw stalk powder extruded into the tapered hole in mold, shear stress continue to increase accordingly. Because the influence of shear stress , elastic stagnation and expansion appear along the diameter direction, and eventually lead to surface cracks after straw stalk pellets were extruded , these cracks influence the molding quality of finished products.

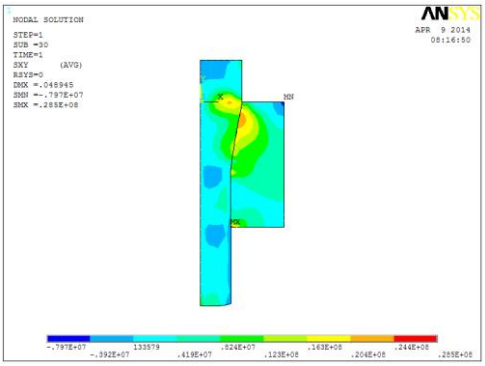

Fig.8 Shear stress chart of the straw in compressing process

5. Conclusion

Through the finite element analysis of the straw stalk powder pressed by the compression molding process, conclusion can be obtained: in the area near the cone hole of annular molding mold, frictional force between stalk material and mold is maximum, stalk pellets are subjected to a large shear stress, stalk material lag in flowing, that is the main reason why stalk pellets form surface crack. Thus we can see that shear stress plays an important role and has deep influence on the quality of stalk compression molding, the increasing of shear stress can increase the density of straw stalk block, but excessive shear stress will lead to cracks on the surface of straw stalk block, structure optimization of annular molding hole can improve the forming quality of stalk pellets.

References

[1] Ning Penghui. Study on densification mechanism of annular molding stalk briquette machine [D]. Hebei: Dissertation of Hebei University of Science and Technology, 2011.

[2] Ooi Chin Chin, Kamal M.Siddiqui . Characterstics of some biomass briquettes prepare under modest die pressuers[J] . Biomass and Bioenergy, 2000, 18:223-228.

[3] Wang Min. Main technical parameters of annular molding pellet machine [J]. Hunan feed, 2006 fourth: 39- 41.

[4] Li You. Virtual design and simulation of five plunger stalk fuel molding machine:[D]. Anshan: University of Science and Technology Liaoning, 2013.

[5] Zhang Chaohui ANSYS12.0 Application case analysis of structural engineering [M]. Beijing: Machinery industry press, 2010.

[6] Wang Fuchi, Zhang Chaohui.ANSYS10.0 Theory of finite element analysis and engineering application [M]. Beijing: Electrical industry press, 2006.

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