

Analysis of Deformation and Equivalent Stress during Biomass Material Compression Molding

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Abstract. Ansys is adopted to analyze mold deformation and stress field distribution rule during the process of compressing biomass under pressure of 20Mpa. By means of unit selection, material property setting, mesh partition, contact pair establishment, load and constraint applying, and solver setting, the stress and strain of overall mold are analyzed. Deformation and equivalent Stress of compression structure, base, mold, and compression bar were analyzed. We can have conclusions: The distribution of stress forced on compressor is not completely uniform, where the stress at base is slightly decreased; the stress and strain of compression bar is the largest, and stress concentration may occur at top of compression bar, which goes against compression bar service life; the overall deformation of main mold is smaller; although there is slight difference between upper and lower part, the overall variation is not obvious, but the stress difference between upper and lower part of main mold is extremely large so that reaches to 10 times; the stress and strain in base decrease in circular shape, but there is still stress concentration in ledge, which goes against service life; contact stress does not distribute uniformly, there is increasing or decreasing trend in adjacent parts, which is very large in some parts.

in constructing both.

1. Introduction

Because of loose texture and small bulk density, biomass raw material contains the shortcomings of small density while high collection as well as storage and transportation cost. Besides, the difficult scale and efficient utilization and poor economic benefit are the major elements restricting the pace of turning biomass into commodity energy. Among the technologies developing and utilizing biomass energy, biomass solidification forming technology can process the low-grade biomass raw material into efficient and clean briquettes fuel, which solves the problems of high biomass storage and transportation cost and greatly enhances the utilization efficiency of biomass resources ^{1,2,3,4}. The use of solid after molding is so extensive that, it can be used as the raw material of living burning ^{5,6,7}, thermal power generation⁸, and gasification⁹; so it plays important supporting role in the development of entire biomass energy industry. Since biomass is the only storable renewable resource, the energy density of its raw material after compression molding is equal to that in intermediate coal, whose combustion characteristics have been obviously improved, such as none black smoke, less flying ash and complete burning. Moreover, biomass briquette fuel can be deeply processed into mechanism charcoal, which carries the advantages of regular shape, high strength, more pores, easy for combustion, burning resistance and pollution free. Based on convenient storage and transportation and less loss, briquette fuel is the renewable energy source easy for commercialized production and sales.

Existing biomass molding equipments also expose serious problems during operation, which restricts the scale development of biomass briquette industry. Therefore, to optimize existing biomass molding equipments, improve equipment productivity, reduce ton energy consumption and increase service life are the key issues need to be solved urgently. By virtue of Ansys software, this paper implements nonlinear contact statics simulation of molding process, which uncovers mold stress and strain distribution rule during molding process and provides theoretical reference for optimizing equipment structure.



1.1. Establishment of Finite Element Model

1.1.1. Establishment of Model. Based on taking distillers' grain as compression fuel, its stress and deformation distribution during compression were researched in this experiment researches. The theoretical model in this research totally adopts the shape and size that are the same as actual model. Compression process indeed is a nonlinear process; however, the process of nonlinearity is so complex that this simulation regards it as a small deformation linear issue. Due to the symmetry of structure and loaded load, axial symmetry is applied to modeling. The model in this analysis originates from Ansys Workbench modeling and the model is shown in Fig.1. Since the establishment is 1/2 of model section, it is axial symmetry model. Elastic Modulus of Distillers' Grain and Distillers' Grain 16000 and 200000 Respectively. Poisson's Ratio is 0.3.

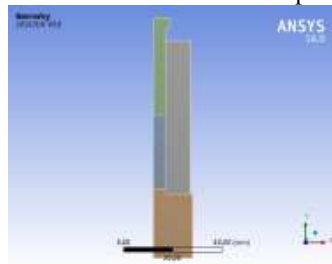


Fig 1. Modeling

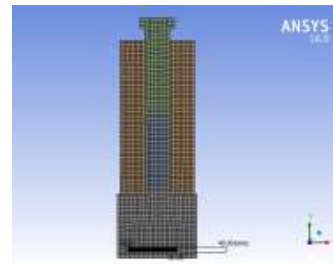


Fig 2. Mesh Generation

1.1.2. Determination of Material Parameter and Property

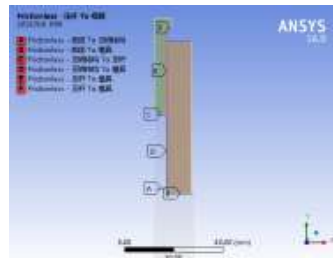
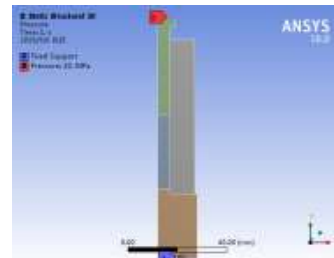
Table 1. Material Parameter.

Material	Elastic Modulus/MPa	Poisson's Ratio
Distillers' Grain	16000	0.3
Distillers' Grain	200000	0.3

1.1.3. Unit Selection and Mesh Generation. This analysis applies Ansys Workbench and mesh module for mesh generation with adopting two-dimensional 8-node plane 183. Because PLANE183 carries quadratic displacement function, it can be better utilized in irregular mesh generation. This unit contains 8 nodes and each has 2 freedom degrees with translation toward directions x and y. This unit can be used as both plane unit (plane stress, plane strain and generalized plane strain) and axial symmetry unit. This unit possesses the abilities of plasticity, creep, stress rigidity, large deformation and large strain. In addition, its capability of force-displacement mixture formula can simulate the deformation approaching to incompressible elastoplastic material with supporting initial stress option.

The module and mesh are divided by using WB mesh so as to partition physical field as Mechanical; mesh relevance =100, and surface mapping mesh generation is adopted. The whole is shown in Fig. 2.

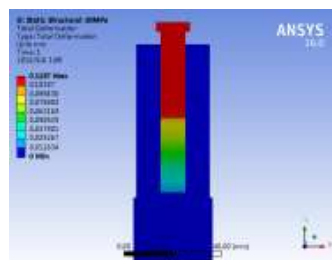
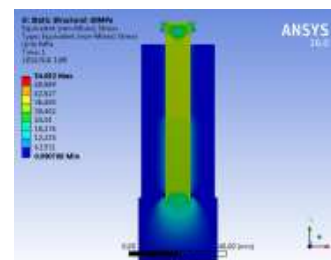
1.1.4. Establishment of Contact Pair, Constraint and Load. During the process of modeling analysis, because mold and distillers' brain both are solid with small displacement, it is available to hypothesize that the relative displacement is unchanged, which means there is no friction. As shown in Fig.3, 5 contact pairs are established in contact state of Frictionless, which is no frictional contact. In the entire analysis, there only is pressure forced on compression bar in the additional load, but the base is fixed, so the adopted constraint is fixed constraint. Displacement constraint is established as shown in the place A of Fig. 4. Pressure is established, whose strength at the place B in picture is 20MPa. Establishment boundary conditions and load are specifically as follows:

**Fig 3.** Contact Pair Setting Diagram**Fig 4.** Constraint Setting and Pressure Applying Diagram

1.2. Statics Analysis Result

The unit selection, material property setting, mesh generation, contact pair establishment, load and constraint applying, solver setting and other earlier preparation of analysis are completed based on above settings. The examination of above set constraint, load and relevant solving parameters is required before solving. Then the following result analysis is acquired:

1.2.1. Overall Deformation and Overall Equivalent Stress. Fig. 5 is the overall deformation of mold. According to it, the mold deformation is small while the displacement of compression bar and compressed fuel is larger. Since displacement is the manifestation of overall deformation situation, the lower part of fuel will definitely be lower than that of upper part with the compaction of fuel, but the displacement of compression bar is the largest. As shown in Fig. 5, overall equivalent pressure diagram indicates that, the pressure on compression bar is the largest, followed by compressor. The stress of base is shown in the Fig.6, the pressure at the contact place of compressor and base is larger while other places is smaller so that it decreases in the form of semi circle.

**Fig 5.** Overall Deformation Diagram under 20MPa**Fig 6.** Overall Stress Diagram under 20MPa

1.2.2. Deformation of Compression Structure and Compression Structure Equivalent Stress. Since the distributions of stress and deformation sizes in different parts are various, the single overall cloud picture cannot display the complete variation situation of each part. Thus, it is necessary to separately analyze the stress of each part so as to obtain more accurate analysis result. The stress of each part is analyzed. Fig.7 is the deformation diagram of compression fuel under 20MPa. As shown in the fig.7, during the compression process, the deformation of the end closer to base is smaller while that in the end closer to compression bar is larger; the deformation at horizontal position is the same. Fig. 8 is the stress diagram of compression fuel under 20MPa. It shows that, the stress forced on fuel is not in uniform distribution, where the slight non-uniform appeared in the place close to base, but the overall difference is not significant without great influence on briquettes fuel; so it can be ignored in practical use.

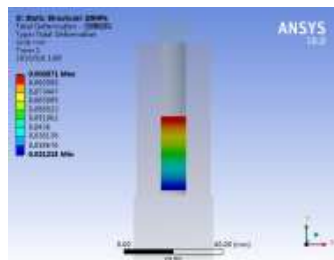


Fig 7. Compression fuel Deformation Diagram under 20MPa

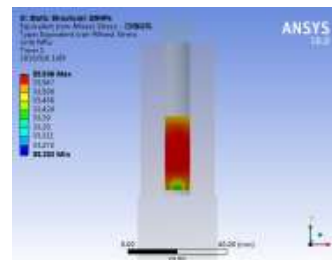


Fig 8. Compression fuel Stress Diagram under 20MPa

1.2.3. Base Deformation and Base Equivalent Stress. Fig. 9 is the deformation diagram of base under 20MPa. It shows that, in base deformation that in ledge of base is obviously larger than the overall part. Meanwhile, the deformation in base decreases in the form of semi circle. Fig. 10 is the diagram of base stress under 20MPa. It shows that, for base, both stress and deformation present the largest at the part close to compressor, and then decreases in the form of semi circle. What needs to come into notice is that, the stress concentration phenomenon is generated at base ledge, which greatly influences the service life as well as reliability of this part.

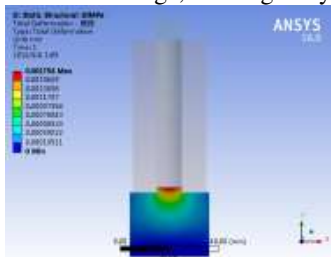


Fig 9. Base Deformation Diagram under 20MPa

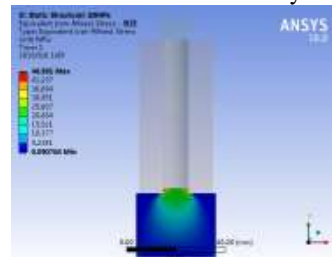


Fig 10. Base Equivalent Stress under 20MPa

1.2.4. Mold Deformation and Mold Equivalent Stress. As shown in Fig. 11, it can be obviously concluded that, the adjacent place of compression bar and compressor increases obviously. However, since mold is rigid body, the change of numerical value is not obvious. As shown in Fig. 12, the stress forced on mold at compressor part is obviously higher than that in upper part. The adjacent part of stress variation is in the contact part of compression and compression fuel. The huge variation of stress in this place has direct influence on main mold.

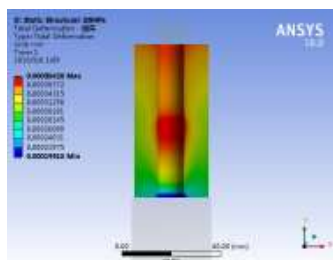


Fig 11. Main Mold Deformation Diagram under 20MPa

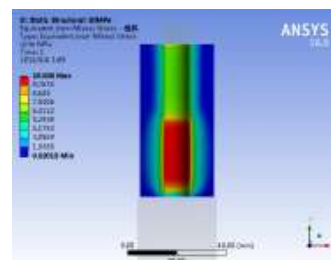


Fig 12. Main Mold Stress Diagram under 20MPa

2. Summary

Due to the existence of extrusion force and friction, the large stress concentration in molding mold is the major deficiency of cylinder molding equipment. The data obtained from simulating and analyzing mechanics during biomass molding, deformation process, stress and strain distribution, and comparing existing experimental conclusions are reliable. Meanwhile, it provides better data as well as method for further research of biology molding mechanism. Based on two pressures, this paper analyzes the stress of the whole and each part under different pressures. The following conclusions are obtained: the distribution of stress forced on compressor is not completely uniform, where the stress at base is slightly decreased; the stress and strain of compression bar is the largest, and stress concentration may occur at top of compression bar, which goes against compression bar service life; the overall deformation of main mold is smaller; although there is slight difference between upper and lower part, the overall variation is not obvious, but the stress difference between upper and lower part of main mold is extremely large so that reaches to 10 times; the stress and strain in base decrease in circular shape, but there is still stress concentration in ledge, which goes against service life; contact stress does not distribute uniformly, there is increasing or decreasing trend in adjacent parts, which is very large in some parts.

Since the stress sizes on mold in different parts are various, particularly that the stress concentration greatly influences mold service life, the suggestions are proposed aiming at above issues: with respect to cylinder fuel molding, because the distributions of stress and strain under different pressures are similar, this analysis can be referred under other stress; in stress concentration part, redesign of mold, heat treatment of material or adoption of better material are necessary; apply different materials to compression bar and other parts because the stress and strain in compression bar are the largest in entire system, or the increase of compression bar appropriately is available; it is available to decrease circular radius or adopt other cheaper material for main mold; it is suggested to use cladding material or heat treatment to the internal contact surface of mold so as to further improve material performance, reduce pitting caused by alternating stress during continuous production, and improve reliability as well as service life.

3. Acknowledgments

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