Engineering in Agriculture, Environment and Food 7 (2014) 34–39

Contents lists available at ScienceDirect

Engineering in Agriculture, Environment and Food

journal homepage: http://mama.agr.okayama-u.ac.jp/AABEA/

Research paper

Shape model of grain and straw using coupling elements and flight simulation of threshing unit of combine by discrete element method

Yuko Ueka [a], Masami Matsui [b,*], Eiji Inoue [c], Muneshi Mitsuoka [c], Takashi Okayasu [c]

[a] *Ehime University, 3-5-7 Tarumi, Matsuyama, Ehime 790-8566, Japan*
[b] *Utsunomiya University, 350 Mine, Utsunomiya, Tochigi 321-8580, Japan*
[c] *Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan*

ARTICLE INFO

Article history:
Received 15 July 2013
Received in revised form
9 December 2013
Accepted 11 December 2013
Available online 27 December 2013

Keywords:
Flight simulation
Grain
Straw
Discrete element method
Coupling element
Combine
Winnowing

ABSTRACT

The threshing unit of a combine comprises a multiphase flow; therefore, it is essential to consider it on the basis of the flow model. In this study, flight simulation by DEM with fixed wind velocity was carried out. The grain and straw were considered to be ellipsoidal and cuboidal, respectively. A two-dimensional model coupling with a circle element was constructed. Each flight trajectory was reproduced in terms of the initial conditions and changes in winnowing velocity. The average flight velocity of the grain was 0.2 m/s higher than that measured in the experiment. It can simulate to closer phenomenon by mixing different particle mass and straw, analyzing the increase in particles and linking it with fluid analysis.
© 2013, Asian Agricultural and Biological Engineering Association. Published by Elsevier B.V. All rights reserved.

1. Introduction

Winnowing is carried out by the winnowing fan in the threshing unit of a combine by making use of the differences in the specific gravities and air drags of grain and straw. Agricultural machine manufacturers need to produce low-cost, high-efficiency machines that have shorter development times. To this end, it is important to understand the flow loci of grain and straw, feed rate of grain, and wind velocity distribution while developing a threshing unit. An effective approach is to incorporate the development process by introducing a numerical simulation for predicting performance.

The threshing units of a combine consist of a multiphase flow: a mixture of grain and straw (solid) and air (gas). The movement of the particles can be explained by following the individual grains independently when the densities of grain and straw are sufficiently low (Matsui et al., 2004b; Furuno et al., 2006). With an increase in particle concentration, the effect of the particle dispersion system as the solid phase on the gas phase as well as on the solid phase increases. Therefore, it is necessary to consider winnowing on the basis of multiphase models. Additionally, as particle spacing decreases and the frequency of particle collisions increases, it is essential to introduce interparticle interaction models using the explicit method.

Models of interparticle interactions such as collision and contact are roughly classified into two groups: hard sphere (HS) and soft sphere (SS). HS models follow the rigid-body collisions of classical mechanics for interparticle collisions. The change in the interparticle relative velocity before and after collision depends only on the coefficient of restitution; given that HS models handle the mechanical process of rigid body collisions directly, they cannot manage simultaneous collisions of more than three particles. In contrast, SS models affect the coefficient of restitution and the friction force, and the individual interparticle coordinates are determined on the basis of the degree of interparticle overlap and repulsion. In general, this is called the discrete element method (DEM) (Cundall and Strack, 1979; The Society of Powder Technology, 2005).

The DEM was adopted as the SS model because the feed rates of grain and straw are involved in multiple interactions.

The trajectories of individual grain and straw particles are complicated and are influenced by the shape and angle by which these particles turn in flight (Matsui et al., 2004a; Furuno et al., 2006). In the DEM, element shapes are mostly spherical, but there are elliptical elements as well (The Society of Powder Technology, 2005; Sakaguchi et al., 1996, 2001).

* Corresponding author.
E-mail address: m-matsui@cc.utsunomiya-u.ac.jp (M. Matsui).

1881-8366/$ – see front matter © 2013, Asian Agricultural and Biological Engineering Association. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.eaef.2013.12.006

In this study, the grain and straw chaff flowing into the winnower were modeled as circle coupling elements, and the flight of the grain and straw under fixed wind velocity conditions was simulated by calculating the interparticle interaction and moment.

2. Materials and methods

2.1. Shape models of grain and straw using coupling elements

The grain was considered elliptical, and the average grain size was determined using grains collected from outlet 1 of the test winnower (Fig. 1). The lengths of the major, middle, and minor axes were 7.9, 3.6 mm, 2.6 mm, respectively, and the mean mass was 0.0268 g. The straw was considered as having a cuboid shape, and the average straw size was calculated using straw collected from outlet 3 of the test winnower. The length, width, and thickness of the straw were 15, 0.7, and 0.5 mm, respectively, and the average mass was 0.0019 g.

The maximum fluid drag toward the grain occurs when the grain presents the maximum projected area against the wind direction; thus, two-dimensional shape models of grain were created on the basis of the major and minor axes of the ellipse, and the shape was approximated using five pieces of grain for circle elements (Fig. 2(a)). In this case, the five pieces of grain were laid out such that the center positions were located at equal intervals, and the radius of each element was established such that that they formed an elliptical circle. The radii of elements 1 and 5 ($i = 1, 5$) were 0.459 mm, those of elements 2 and 4 ($i = 2, 4$) were 0.940 mm, and that of element 3 ($i = 3$) was 1.296 mm. Here, i denotes the circle element number, as shown in Fig. 2. Similarly, straw particles were considered on the basis of the maximum projected area. The shapes were close to that of a plate, and two-dimensional shape models based on length and width were adapted. Thirty circle elements, each having a radius of 0.25 mm, were connected (Fig. 2(b)).

2.2. Discrete element method

2.2.1. Mechanical model of discrete element

a. Contact Judgment

Contact elements were proposed by Iwashita (1991). The contacts among the contact elements were determined using the same

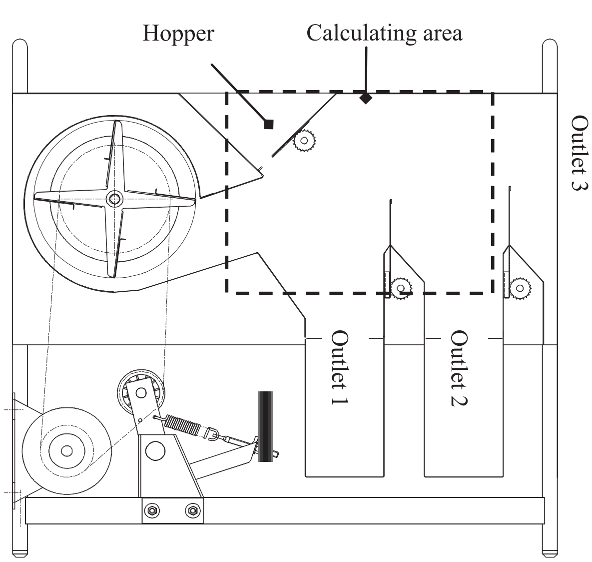
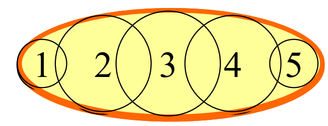
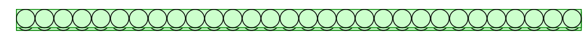


Fig. 1. Tested winnower.



(a) Grain



(b) Straw

Fig. 2. Shape model.

methods as those for the circle elements. Fig. 3 shows the key map of the elements in contact.

For the case when the spacing between two connected contact elements is smaller than the center of gravity spacing of the element, the relative amount of penetration of the element was calculated as follows:

$$r_i + r_j \geq L_{ij} \tag{1}$$

where L_{ij} denotes the distance between the centroids of contact elements i, j; it is expressed as follows:

$$L_{ij} = \sqrt{(x_i - x_j)^2 + \left(y_i - y_j\right)^2} \tag{2}$$

To determine interwall contact, equation (3) was used as follows:

$$r > \frac{|ax + by + c|}{\sqrt{a^2 + b^2}} \tag{3}$$

where r: Distance between center of element and contact point; x, y: Center coordinates of element; a, b, c: Coefficients of tangent equation of wall surface.

b. Displacement increments at contact point

For calculating the contact force, each contact point was calculated; the force acting at the center of gravity of the contact elements and the moment were calculated for each contact situation. As shown in Fig. 3, a situation that did not exist previously is developed at the location where the contact point is linked to the center of contact element O_iO_j. Therefore, the effect of an increase in turning change on i, j with an increment in the relative displacement along the normal direction at the contact point must be

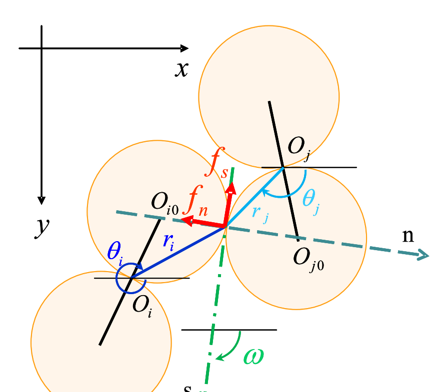


Fig. 3. Contact judgment between two coupling elements.

Download English Version:

https://daneshyari.com/en/article/4508410

Download Persian Version:

https://daneshyari.com/article/4508410

Daneshyari.com