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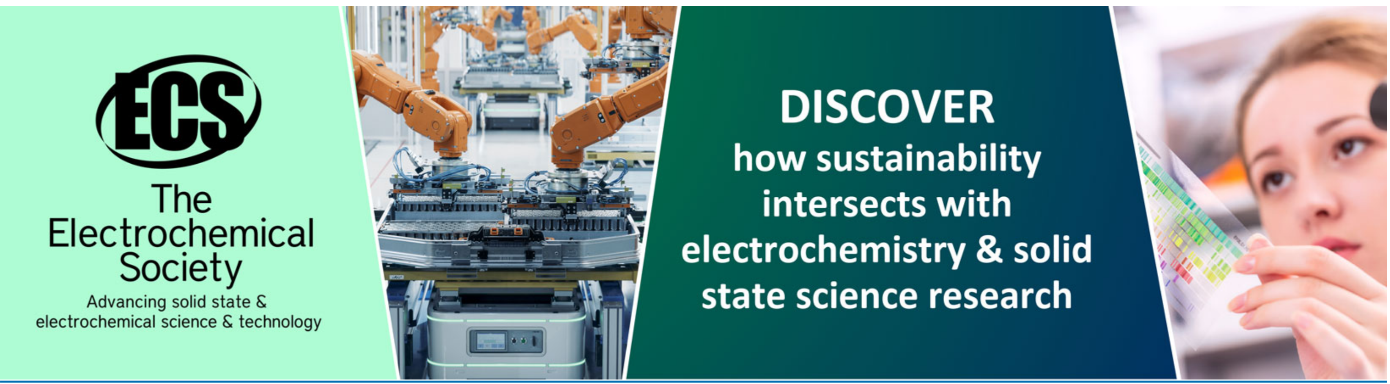

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Numerical Simulation of Sugarcane under Wind Load

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Abstract. For difficulties in establishing complex coupling dynamics model of sugarcane-soil-wind system and the dynamic response process of sugarcane by wind effect is unknown problems, establishment of complex coupling dynamics model of sugarcane-soil-wind system was discovered. ALE (Arbitrary Lagrange-Euler) method and soil more hierarchical modeling technology were used in the model. And dynamic response process of sugarcane under wind load was analyzed. Result shows that the modeling method is feasible which can be used on the research of sugarcane lodging. Periodic decay reciprocating vibration occurs in the process.

1. Introduction

At present, the study of sugarcane lodging was mainly concentrated upon different varieties of sugarcane, different depth of implant, hilling up with earth on the process and others' aspects, which researched by sugarcane planting contrast tests. However, the sugarcane lodging experiments effected by multiple factors and comprehensive kinetic mechanism have been made rarely. The region which affected badly by the typhoon, the monsoon lack the effective lodging-resistant measure so that sugarcane lodging badly. The study of the dynamic response process when sugarcanes under wind load and the kinetic mechanism of sugarcane lodging are the foundations of the study of sugarcane lodging. But sugarcane lodging is influenced by many factors. There's tight coupling between this factors and the coupling relationship in between is complicated. In the process of sugarcane lodging, soils produce large deformation and rupture so that it is hard to learn about the dynamic response process when sugarcanes under wind load and the kinetic mechanism of sugarcane lodging when we use general physical test and the finite element method. Accordingly, in this paper, ALE (Arbitrary Lagrange-Euler) method and soil more hierarchical modeling technology were used, to study the numerical simulation of establishment of complex coupling dynamics model of sugarcane-soil-wind system and build the numerical simulation of the dynamic response process of sugarcane by wind effect. It provides the basic theoretics as required for study of sugarcane lodging.

2. The establishment of the numerical simulation model

2.1 The geometric model

The sugarcane-soil-wind dynamic system consists of sugarcane, soil, wind source and air. Among them, the sugarcane is composed of leaves, leaf sheath, stem and roots. As shown in figure 1, due to the complexity of structure of the leaves, the leaf sheath tightly wrap around the stem and meanwhile thanks to the tininess and abundance, the roots have the anchoring effect, as a result, once the sugarcane lodges, its roots near the stem will fasten the soil into a approximately cylindrical soil plate, as shown in figure 2. Therefore, in order to facilitate modeling, according to the structures of leaves and leaf sheath, and the condition where the leaves are subject to the wind, as well as the anchoring effect that the roots exert on the soil, this paper simplifies the sugarcane as follows:

(1) Give the same treatment to the thickness and materials of each part of the leaves, and leave out the too soft part of the leaves' end.

(2) Remove the leaf sheath, connect the leaves and the stem directly, besides, deal with the stem as a regular eight-angular prism made of homogeneous materials.

(3) Replace the anchoring effect existing between the sugarcane roots and the soil with the cylindrical soil plate.

Figure 1. Sugarcane

Figure 2. Cylindrical soil disc

The mesh quality directly affects the accuracy of the results of numerical simulations, thus, in this paper, to obtain good mesh quality in mesh generation, the wind source, the air and the soil are modeled into a rectangular shape. Additionally, as the property of the arable layer's soil changes greatly with the depth changing [1], soil modeling should be conducted in accordance with different layers. At the same time, to ensure the deformation of the soil's surface can be observed when the ALE simulates the soil, a thin layer of air will be built on the surface. What's more, the size of the win source-air-soil geometric model will depend on the scope in which the sugarcane is subject to the win, and the deformation and rupture of the soil. Since the scope where the stem is impacted by the wind is rather small, the model will rule out the air near central part of the stem. This paper adopts the geometric model of the sugarcane-soil-wind coupled system jointly established based on Pro/E and ANSYS/LS-DYNA as shown in figure 3.

2.2 Mesh generation and loading

Above all, the mesh size at the place where materials are coupled should be as the same as possible, otherwise, the penetrating phenomena could happen in the process of coupling [2], consequently, the leaves and the upper part of the stem may couple with the wind, while the plate with the soil. So the meshes of the leaves and the stem should match with that of the air, while the mesh of the plate shall be line with that of the soil. Moreover, to improve the mesh quality, the meshes of the leaves and stem are generated by the sweep method; those of the wind source, the air and the soil are done by the mapped method; and that of the soil plate is by the free method. To guarantee the material exchanges and transportation between the wind and the air, between the soil and the thin air layer, and between different soil layers, the interface nodes are converted into public node. Furthermore, in order to simulate infinite air and soil domains and keep gravitational wave from influencing the calculation results, the boundary surface between the air and the soil is defined as the no reflection boundary. Lastly, the other parameters of the win source can find their definitions in references [2-3]. And the established cutaway view of the finite element model of the sugarcane-soil-wind coupled system could be seen in figure 4.

2.3 The material model

When the sugar cane-soil-wind coupling system modeling, each component adopts hexahedral SOLID 164 unit. Pouring air, air and thin layer chromatography is defined as the blank material, density of 1.29 kg/m³, by the pressure of -1 Pa, dynamic viscosity coefficient of 1.7456×10^{-5}Pa s, specific heat ratio γ of 1.4. Become a thin layer of air state equation, the air and the linear polynomial equation of state [2-3]. Sugarcane leaves, stems are defined as elastic material, its material parameters measured by physical experiment. Soil disc material parameters take average material parameters of the soil. Soil is defined as the FHWA soil material, the modeling of the soil material parameters measured by physical test and application of reverse technology [4].

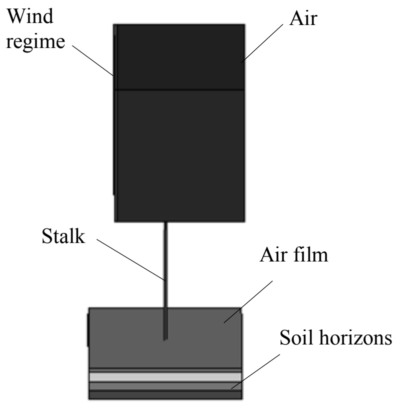


Figure 3. Geometric model of the sugarcane-soil-wind complex coupling system

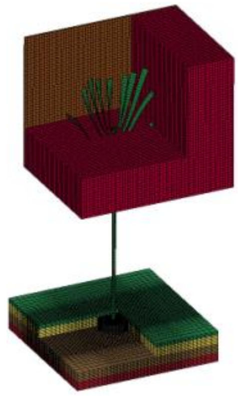


Figure 4. Section view of finite element model of sugarcane-soil-wind coupling system

2.4 The main control parameters

Pouring, air, thin air and soil layer of solid elements ELFORM algorithm parameters are set to 11 (multi-material ALE), AET algorithm parameter is set to become an entity unit 4 (include units). ALE_MULTI - MATERIAL_GROUP for pouring and air with keywords, thin layer between air and soil, the exchange of material between layer and layer of the soil and transport. Wind and sugar cane coupling, coupling between the soil and soil plate adopts way of penalty function, coupled integral number is set to 4 to reduce leakage.

3. Validation of modeling method

Based on the field of physical test methods, through the system of physical experiment results and the comparison of the results of numerical simulation, Validation using the ALE method and soil more hierarchical modeling technology to construct a system of sugar cane - soil - wind coupling numerical simulation model method is feasible. In order to make the field experiment of physical experiment and numerical simulation system conditions are consistent, field experiment uses the air blower generated are, at the same time, the determination of the related parameters in the field experiment in sugarcane and soil, establish verification with sugar cane - soil - wind composite system numerical simulation model, sugar cane and the related parameters of the soil determination method in reference [4-5].

3.1 Test equipment and venues

The main testing equipment: strong industrial fan (model: FS850, Foshan Shunde Leliu de sheng electrical appliance factory, impeller diameter: 850 mm, power: 480 w, the wind speed stability of the gear), digital anemometer (model: GM8902, Shenzhen poly alum source technology co., LTD., resolution: 0.01 m/s), vibration tester (type: DH5938, Jiangsu Donghua testing technology co., LTD.), acceleration sensor (DH131), laptop, etc. Testing ground for sugarcane planting base in Guangxi University, 17 sugarcane varieties for gardens, test time is in November 2014.

3.2 Test method

Field physical test, first choose from sugarcane planting base via a stem straight, no insect pest, the growth of normal sugar cane as a test sugar cane, after clearance test near the sugar cane sugar cane and other sundry, and eliminate the environment influence on test results. At the same time, the clearance test sugarcane leaves and cut off the leaves on the part of the terminal is too soft. And to eliminate the influence of natural wind to test, test in the natural wind speed is low (not more than 0.2 m/s) of time. Test at the same time, fan motor axis aligned with sugarcane stalks, fan out the wind and sugarcane leaf surface parallel to the wind. Sugar cane by wind function test system diagram as shown in figure 5, the mark point height H = 110 mm, the distance between the fan and sugar cane L = 500 mm, H_0 = 230 mm. Test on site are shown in figure 6.

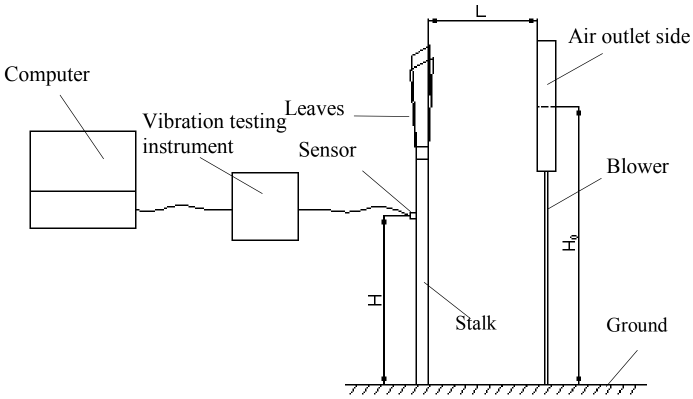


Figure 5. Diagram of sugarcane testing system

Figure 6. The test site

3.3 Material parameters and relative geometric dimensions of the model

According to the test methods of reference [4-5], we measured sugarcane and the corresponding soil material parameters, the average wind speed of the fan, soil and soil anchor plate size roots formation. The results of the material parameters for the modeling of sugarcane are shown in Table 1, the material parameters of the soil model for the test of sugarcane are shown in table 2.

The diameter of the soil plate is 21.8cm, the height of the soil plate is 15.2cm.The average wind speed of the fan is 5.5m/s. The wind regime was applied by the keywords "BOUNDARY_PRESCRIBED_MOTION_OPTION", and the size of the wind regime is the same with the size of fan. For the test of sugarcane stalk length and average diameter were 219.7cm and 2.998cm.The geometrical dimensions of the leaves are shown in table 3.A simplified model of the leaves as shown in Figure 7, leaf and stem leaf angle and torsion angle as shown in figure 8.

Table1. Physical parameters of sugarcane

Name	Average density $/g\cdot cm^{-3}$	Average elastic modulus /MPa
leaf	0.769	1460.3
Stalk	1.051	1250.2
root hair	0.709	649.7

Table 2. Parameters of soil material

Layers' No.	Moisture content /%	density $/g\cdot cm^{-3}$	Cohesion /kPa	internal friction angle /°	Elastic modulus /MPa
1	25.76	2.08	13.49	23.06	0.99
2	24.45	1.87	15.08	22.85	1.08
3	24.18	1.97	24.23	22.19	1.30
4	23.34	1.98	28.92	21.67	1.25

3.4 Test results and analysis

Figure 9 is the acceleration curve of the marked point, among them, the solid line is the acceleration curves of physical test, the dashed line is the acceleration curves of numerical simulation test. From figure 9 we can see, the results of numerical simulation are in agreement with the results of physical experiment. Figure 10 is a numerical simulation screenshot of the deformation process of sugarcane, from figure 10 we can see, under the action of the wind, firstly, sugarcane produces large bending deformation, then the partial rebounds, and lets the stalk reciprocating swing. This phenomenon is consistent with the observed in physical experiment. It is proved that the method is feasible for the construction of the numerical simulation model of sugarcane soil air coupling system, and the model is high precision.

Table 3. Size of sugarcane's leaves

Leaves' No.	average value /mm						*The angle between the leaf and stem θ/°*	*Torsion angle of leaf α/°*
	Tip distance h_1	Leaf Length l_2	Front leaf width h_2	Maximum leaf width h_3	Front point to Maximum point l_1	vane thickness w		
1	414	726	23	55	709	0.26	35	23
2	265	701	22	56	693	0.26	23	65
3	121	654	24	56	649	0.25	18	68
4	28	583	21	58	556	0.26	13	71
5	0	525	23	58	498	0.27	1	89

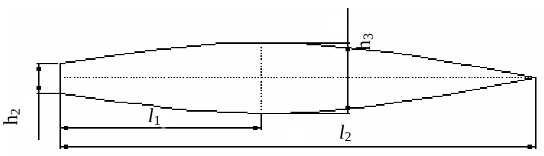


Figure7. Sugarcane leaf

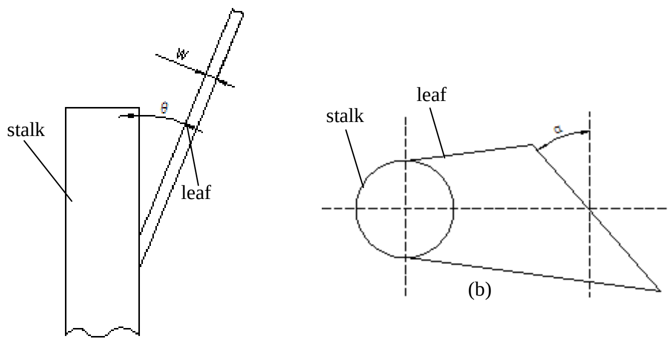


Figure8. Geometric parameters of leaf

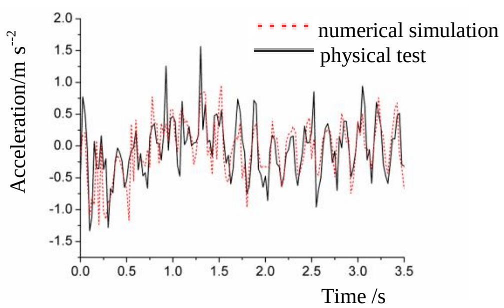
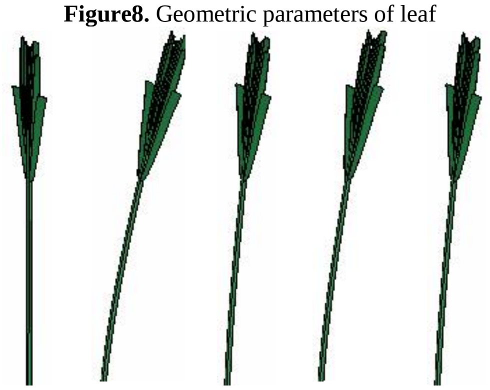


Figure9. Acceleration curve of the marker

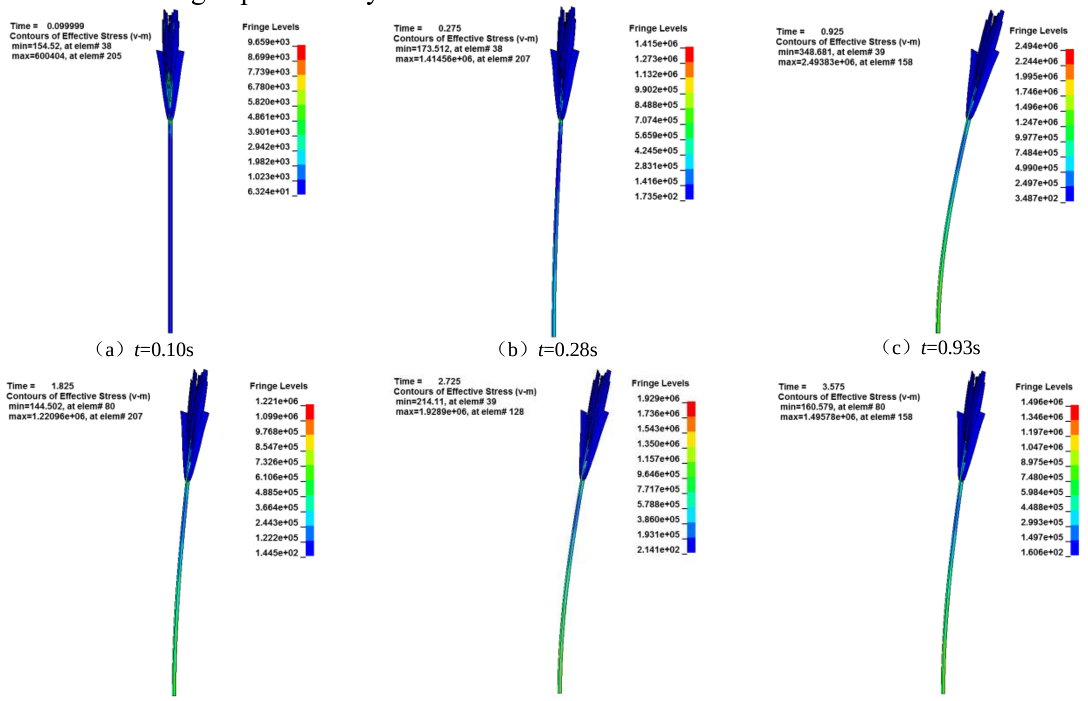


（a）t=0.00s（b）t=0.93s（c）t=1.83s（d）t=2.73s（e）t=3.58s

Figure 10. Deformation of sugarcane

4. Analysis on the process of stress change of sugarcane

Figure 11 is the numerical simulation screenshot of the process of stress change of sugarcane in numerical simulation test. From figure 11 we can see, when t=0.1s,sugarcane started by the effect of wind, the place of leaves and stem connection first appeared greater stress, and the stems came into being slight deformation. With the wind continued to function of sugarcane, the deformation of stems increased gradually, the stress of stem roots also increased gradually, when t=0.925s,the deformation of stems reached the maximum, the stress of stem roots also reached the maximum(2.49MPa).At the same time, after the deformation of stems reached the maximum, its rebounded, during the rebound process, the stress of stem roots gradually reduced, when t=1.825s, the springback of stems reached maximum, stem root stress is reduced to the minimum value, the maximum stress occurs at the junction of the leaves and stems, the value is 1.22MPa.Becouse of the reciprocating swing of the stems, the stress also changed periodically.



（a）*t*=0.10s （b）*t*=0.28s （c）*t*=0.93s

（d）*t*=1.83s （e）*t*=2.73s （f）*t*=3.58s

Figure 11. Change process of sugarcane's stress

5. Conclusion

(1)The method of constructing the numerical simulation model of sugarcane soil wind coupling dynamic system is feasible which can be used on the research of sugarcane lodging, and the accuracy is higher by using the multi material ALE method and the soil layer modeling technique.

(2)Under the action of wind, cane to produce periodic attenuation of the reciprocating vibration, the stem stress present attenuation change periodically.

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Acknowledgments

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