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Research on Compressed and Dynamic Variation Law of Alfalfa Grass Sheet During Baling Process

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Abstract: Taking High quality alfalfa hay as the research object, we carried out the test at herbage material baling test bench in different cross sections, and we had emplaced two sets of mobile pressure sensing device and three types of displacement sensor, and we also had collected the signals of thickness, compression force and location of grass sheet through virtual instrument acquisition system in the process of compression. Through the data analysis and processing, we obtained compression and dynamic distribution law of grass sheet on alfalfa in the process of baling. Results show that: the compressed area of grass sheet can be divided into three sections in the process of baling - compressed section, stable density section, density recovery section. Noted that there is a process of stress relaxation which is natural formation in stable density section, and the process made the elastic recovery stress of grass sheet decreasing, therefore, it is best to conduct baling in this section, because it helps to improve the stability of the bale shape. The test results provide a theoretical basis for optimization design of herbage material baler and improving the performance stability of the bale. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Alfalfa, Baling, Density, Compressed, Baler.

1. Introduction

Alfalfa is the preferred fodder crops to develop the sustainable agriculture, but it needs to be compressed into grass products, such as bale, grass blocks, grass particles, etc. in exploitation and utilization, in order to adapt to different uses and transportation needs, increasing their economic value and marketability. Baler is the major equipment to produce bale, but the majority of domestic baler were designed by analogy or surveying and mapping methods, and it was hard to ascertain matched power and other parameters of main parts of baler, which had hindered the further development of grass industry in China. Although scholars from different countries had reached some valuable achievements [1-4], according to the large number of conducted herbage compression characteristics tests research from different sides or different factors, based on the actual needs of produce, but most of those were drawn under laboratory conditions of uniform section in the closed model. In recently years, most of the research achievements on baling process focused on deformation recovery law, compression force change law, etc. [5, 6]. However, we lack of the research on density of grass sheet during baling process. The experiment taking a grass sheet as the research object had studied baling characteristics under different cross sections, and the experiment results revealed compressed

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and dynamic distribution law of grass sheet in the process of baling in order to find the ways reducing deformation recovery, improving bale density, lowering power consumption, ensuring the stability of bale shape. Therefore, those measures not only provide the basis for the structural design parameters of baling chamber and power selection of baler, but also lay the foundation of optimal design for baler.

2. Test Materials and Test Methods

2.1. Test Materials, Devices and Instruments

Choosing dried Medicago sativa as the compressed material, and under the conditions of baler chamber length, initial density, moisture content of grass material and other factors were certain, our carried out compression test in the herbage material baling test bench [7]. Our regard the amount of feed of Medicago sativa per time as the research object, using two sets of force-sensing device which were designed specifically and a type of NS-WY03-300L and two types of NS-WY03-900L displacement sensor in order to measure thickness of grass sheet and compression force in every position of baler chamber, etc. Collecting interrelated force and displacement signals by using virtual data acquisition system, we can obtain indirectly the density of grass sheet in every position from its thickness. Finally, our conducted data processing and analysis through MATLAB software, and the results revealed compressed and dynamic variation law of grass sheet in the process of compression. The test system block diagram shown in Fig. 1.

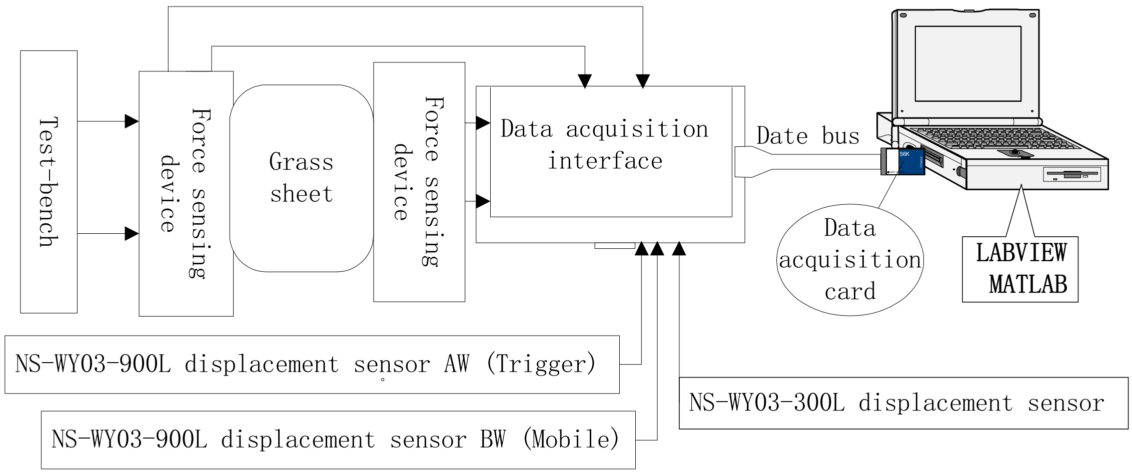

Fig. 1. The test system block diagram on alfalfa in the process of baling.

2.2. Test Methods

When performing the baling test of alfalfa, the amount of feed is 4 kg/time, and the corresponding initial density is 56.83 kg/m^3. Materials should be weighed as required amount of feed, stacked well. According to the requirements of moisture content when baling which is prescribed in JB/T5166-1991 baler grass test methods so that the moisture content of alfalfa about 17 % [8].

Insert grass device need to be removed during tests, and baler chamber need to be adjusted according to pre-set cross-sectional size, selecting the corresponding pressure plates installed on the piston. Starting test-bed, feeding alfalfa, conducting compression, making the material filled with the entire baler chamber, and established stable pressure. Then choosing two sets of force-sensing device which were installed in the feeding chamber in accordance with test requirements, adjusting volume of feeding chamber by the initial travel switch, making two sets of force-sensing device against with pressure plates and grass sheet that had been compressed already, meanwhile, each displacement sensor were also need to be installed in the corresponding position. We adopt with the method of artificial feeding putting 4 kg alfalfa into the feeding chamber evenly during tests, and making it filled with feeding chamber, conducting compression, and record the signals.

3. Results and Analysis

In the process of compression of herbage material, the density grass sheet is a very important basic parameter, generally we obtained value of the density by adopting with indirect measurement method. The tests by measuring the thickness of grass sheet obtained the density of grass sheet. Because the density of sheet grass depends on the thickness of the grass sheet when the mount of feeding is a constant during compression, both have the following relationship:

$$\gamma = \frac{G}{a \times b \times h} \times 10^{-3}, \tag{1}$$

where:
G is the mount of feeding, kg/time;
a×b is the baler chamber cross-sectional area, mm^2;
h is the thickness of the grass sheet, mm;
γ is the density of grass sheet, kg/m^3.

In order to study compressed and dynamic distribution law in baler chamber during compression, we explored the effect on the density distribution law of grass sheet when cross-sectional area of baler chamber changed. We had analyzed and calculated the displacement signals which were recorded by the NS-WY03-300L and NS-WY03-900L type displacement sensor under different cross sections, so we obtained the values of thickness, density and location in the baler chamber when grass sheet was compressed each time. We had done density distribution law figure of alfalfa along the direction of the baler chamber under different cross sections when grass sheet were compressed and recovery. Here only given in Fig. 2, Fig. 3, and other cross-sections are also substantially similar laws.

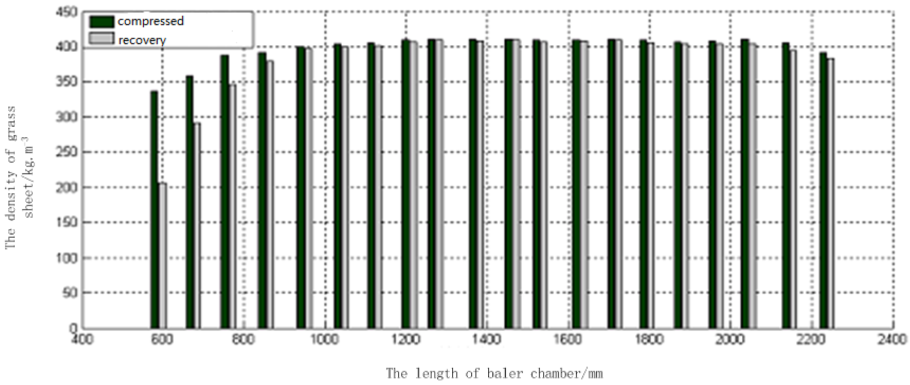

Fig. 2. The density dynamic distribution law in baler chamber when grass sheet were compressed and recovery (alfalfa: 360 mm×460 mm).

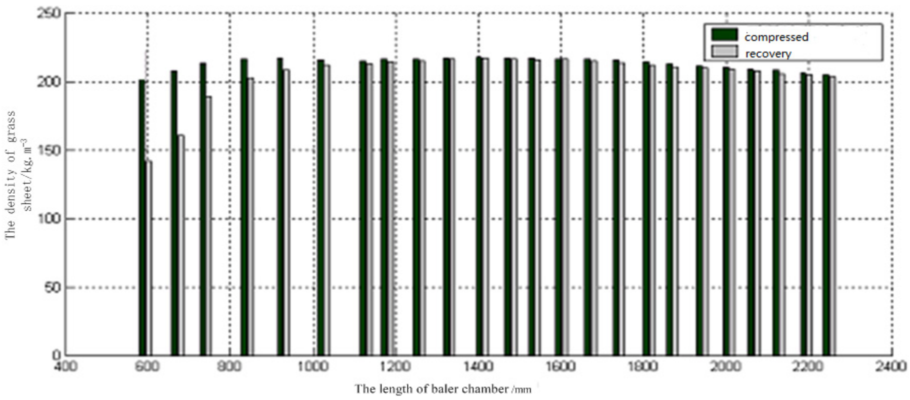

Fig. 3. The density dynamic distribution law in baler chamber when grass sheet were compressed and recovery (alfalfa: 510 mm×460 mm).

As can be seen from figures, we can know density of each grass sheet in baler chamber during compressed and recovery. The tests showed that the distribution law density of each grass sheet during compressed and recovery in baler chamber are essentially same under different cross-sections. According to distinct compressed status of grass sheet in baler chamber, we can divide it into three different sections - compressed section, stable density section, density recovery section. In compressed section, the density of each grass sheet showed a gradually increasing tendency during compressed and recovery, and the compressed density greater than the recovery density. This is due to generate deformation recovery of grass sheet when the piston return travel, and bring about density of grass sheet reducing. The biggest difference of density existed in the first grass sheet during compressed and recovery, with the number of compression increasing, the gap between the both decreased gradually. The density of grass sheet reached the maximum after several times compression, then it began to enter the stable density section, and the tests showed that the density of grass sheet are basically close during compressed and recovery. The previous grass sheet was continually gone back by the new one in stable density section with the reciprocating motion of the piston. Therefore, the density (thickness) of grass sheet remain unchanged basically, under the action of the side pressure from baler chamber, friction produced by baler wall and grass sheet, axial force from adjacent grass sheet .That is, it forms a local strain basic constant region where generated stress relaxation. Internal elastic recovery stress of grass sheet decreased with time, which generated a process of stress relaxation which was formed naturally during compressed. The longer retention time grass sheet in this section or the longer relaxation section, the smaller internal elastic recovery stress of grass sheet, and more conducive to the stability of bale size, therefore, it is best to conduct baling in this section. Grass sheet began to generate deformation recovery after entering the density recovery section, so that the density of grass sheet tends to decrease, and the results making the density of product is less than the maximum density.

In order to further study distribution laws on the maximum axial compression force and the density along the baling chamber in the process of baling on alfalfa, we conducted normalization processing on the maximum axial compression force and density grass sheet, shown in Fig. 4.

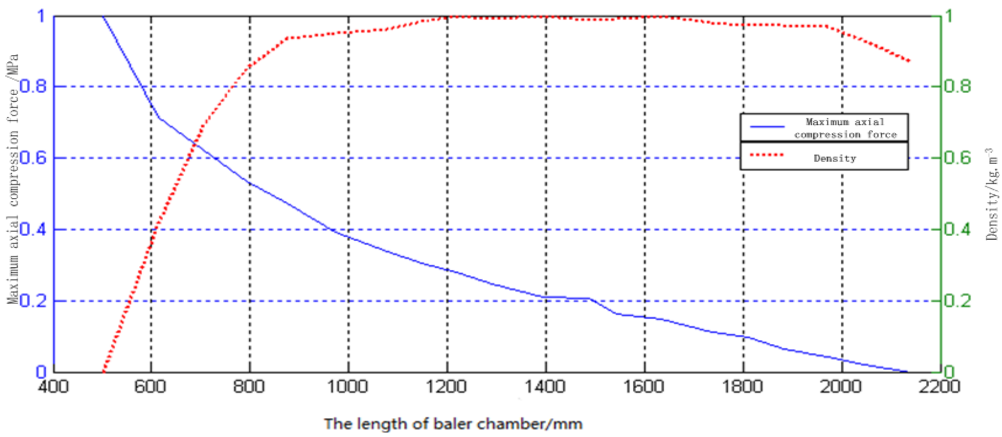

Fig. 4. The relationship between the maximum axial compression force and the density distribution along the baling chamber after normalization processing. (alfalfa: 360 mm×460 mm).

As can be seen from the Fig. 4, alfalfa was obtained the maximal compression force when the first compressed in the whole process of compression, but the corresponding density was not the maximal one in the process of compression. We had done many times loading - unloading cycle compression to make grass sheet gradually compressed after forming grass sheet, but it still generated compression - deformation recovery. Density of grass sheet reached maximum and remained the state in a long section at a certain position in the whole process of compression, and the corresponding compression force was less and it also can generate stress relaxation, and the position was just located in stable density section. Therefore, we should make a longer stable density section when the baler will be designed or produced, reducing the elastic recovery stress, conducting baling timely, improving the stability of the grass product shape.

4. Conclusions and Discussion

1) It reveals compressed and dynamic distribution law of alfalfa along the length of baler chamber under different cross sections in the process of baling, and it showed that the compressed area of grass sheet are divided into three section in the process of baling - compressed section, stable density section, density recovery section.

2) Grass sheet generated deformation recovery under the action of cyclic loading, causing the density of product is less than the maximum density of grass sheet. Pointed out that grass sheet generated a process of stress relaxation which was formed naturally in stable density section, making the internal elastic recovery stress of grass sheet decreasing. Therefore, it is best to conduct baling in this section, and it helps to improve the stability of bale shape.

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