

Effect of temperature on the static compression of molded pulp products

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Abstract. In this paper, the static compression overall performance of molded pulp under different temperature were studied by experiments. The moisture content and elastic modulus of molded pulp materials, the static compression on molded pulp products were studied under the temperature of 5°C, 23°C, 40°C. And the products overall load - displacement curve were analyzed. The second article buckling load relatively high under the temperature of 40°C, the humidity of 50%. When the temperature decreases from 40°C to 23°C and 5°C, the second article buckling load decreases by 16.7% and 30.0%.

Introduction

Molded pulp cushion packaging is typically made out of recyclable papers or other natural plant fibers, and it often has particular cavity structure. The cushioning performance of molded pulp product relies on its structure to absorb energy and to extend the energizing time[1,2]. The use of molded pulp products has become more attractive, than traditional materials like expanded polystyrene foam due to low price of recycled paper, environmental benefits such as biodegradability, and low cost of production[3-5]. It has been become the heated material and the researches focus on the cushion performance of molded pulp materials, the analysis of the typical structural units and the static mechanical performance of molded pulp product. However, relatively few studies on environmental factors of molded pulp product[6-9]. Fully consider the impact of changes in environmental factors on the performance of molded pulp is important for the development of molded pulp industry. Recently, domestic and foreign scholars in environmental factors on molded pulp focused on strain rate, humidity, and loading rate and so on. Zhiwei Wang et al. [10-12] studied the effect of strain rate, humidity and other factors on the pulp molding cushion capacity and energy absorption. Sorensen et al[13] studied the moisture absorbency of molded pulp material under different humidity. Hongwei Ji[14] studied the effect of different loading, temperature and humidity conditions on the mechanical properties of molded pulp materials. But little has been published on the effect of temperature on cushioning properties of molded pulp products, molded pulp cushion packaging design can only judge based on experience. In the actual distribution process, many packages will encounter severe temperature changes, and temperature changes will affect the mechanical properties of molded pulp material, resulting in product cushioning properties change. In this paper, results from the investigation of three typical temperatures on static compressive properties of molded pulp products are presented. And the typical temperatures for the three groups were 5 °C, 23 °C and 40 °C.

Experimentation

Materials and equipment

Experiments were carried out with the molded pulp packaging supported by Huilin Packing Co., Ltd as shown in Fig.1. Its raw material was cane syrup. The material samples were cut from molded pulp products, and the size was 234mm×170mm×95mm. The average thickness of samples was 1.67mm, and the average density was 0.325g/cm³.

Test instruments are: Adjustable pitch cutter, vernier caliper, measuring the thickness of the electric meter (PN-PT6), balance, computer-controlled material testing machine (CMT6104), Humidity Chamber (HPX-250B5H-III), multifunction infrared moisture meter (DHS20-1).



Figure 1 molded pulp cushioning packaging products



Figure2 Tensile specimen

Experimental Methods

Preparation of the sample

Specimens of moisture content determination are flat site which cut from molded pulp products.

The tensile tests were based on ISO 1924-2[14].The specimen used for tensile testing is as shown in the Fig.2. The basic data of Specimen in table 1.

The specimen used for static compression testing is as shown in the Fig.1.

Table 1 specimen size

Number	t Thickness (mm)	L Length (mm)	b Width (mm)	Cross-section (mm ²)	Clamp distance(mm)
1	1.627	70.2	15.40	25.06	49.78
2	1.690	70.5	14.98	25.32	50.00
3	1.719	69.8	15.20	26.13	47.82
4	1.677	70.0	15.10	25.32	49.76
5	1.682	69.9	15.38	25.87	50.12
6	1.419	70.4	14.96	21.23	49.88
7	1.690	70.8	14.70	24.84	50.24
8	1.685	69.7	15.72	26.49	50.04
9	1.639	70.1	15.08	24.72	51.12
10	1.883	70.4	14.92	28.09	52.06
11	1.879	70.1	14.86	27.87	49.74
12	1.602	69.9	14.80	23.71	50.86
13	1.493	70.3	14.80	22.09	50.12
14	1.649	70.4	14.70	24.24	51.19
15	1.725	67.7	15.10	24.32	48.76

Experimental Environment

The tests were based on GB4857.2-87.The molded pulp material samples and molded pulp products were placed in constant temperature and humidity inside the buffer pretreatment for 48h,and the pretreatments temperature respectively were 5 °C, 23 °C, 40 °C, the pretreatment humidity were 50%.

Test

(1) The determination of moisture content test

Based on GB/T462-2003《Determination of moisture content of paper and paperboard》,the specimens were put in multifunction infrared moisture meter for 30mins after pretreated, and the drying temperature was 105°C. Ensure that each tested specimen into the mass between 3-5g. And record results at the end of experiment.

(2) Tensile test

1-15 specimens per 5 into a group, and every specimen were tested after pre-treated at different temperatures. The rate of elongation was set to 12mm/min.

(3) Static compression test

The reference test standard is GB8168-87. The compression test of samples was completed by using CMT6410 computer controlled material testing machine. The rate of compression during the experiments was set to 12mm/min. The maximum allowed compression was 50mm.

Results and analysis

Moisture content of molded pulp material under different temperatures

By measuring each set of five specimens averaged moisture content, obtain the results as shown in table 2. Molded pulp moisture content decreased with increasing temperature. When the temperature decreased from 40°C to 23°C and 5°C, the moisture content decreased by 12.5% and 29.0%. The reason is the same humidity conditions, as the temperature rises, molded pulp water molecules activity increased energy, thermal vibration energy fiber macromolecules increased. It will diminish the water molecules and fiber bonding hydrophilic groups, so that the water molecules were more readily escape from the molded pulp material, so that the moisture content decreased. At the same time, the temperature rises, the water molecules inside the voids of the fibers easier evaporation, the moisture content decreased.

Table 2 Experimental results of moisture content of molded pulp material under different temperature

Temperature (°C)	5	23	40
Moisture content (%)	16.72	14.63	11.87

Mechanical properties of the molded pulp after treatment under different temperatures

The stress-strain curve of molded pulp material as is shown in Fig.3. The curves of molded pulp material under three temperatures pretreatment were the same trend. When the specimen was stretched, molded pulp material stress and strain increased linearly, when the force reached the elastic limit, molded pulp material cracked, the stress - strain curves rapid declined, until the specimens were pulled off. This is because in the beginning, molded pulp material was elastically deformed, the stress increases with strain enhanced, when the load reaches the critical load pulp molding material, the material cracked, the load bearing decreased rapidly, stress was reduced, until the specimen pulled off.

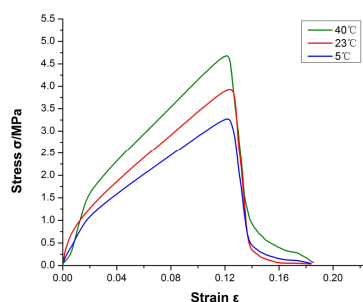


Figure3 stress - strain curve of molded pulp material in different temperature

According to the stress-strain curve of molded pulp material, elastic modulus and yield strength were obtain as shown in table 3.

Table 3 molded pulp material mechanical properties under different temperatures

Temperature (°C)	Yield strength (MPa)	Elastic modulus (MPa)
5	3.27	21.39
23	3.93	26.80
40	4.68	30.24

From table 3, elastic modulus and ultimate strength of molded pulp material is relatively large under the temperature of 40°C. When the temperature decreased from 40°C to 23°C and 5°C, the average yield strength decreased 16.0% and 30.1%, the elastic modulus decreased 11.3% and 29.3%. Integrated moisture and elasticity modulus data, it is obvious that decreased moisture content will increase the strength of the material, making it the ultimate stress and elastic modulus increased

static compression performance of molded pulp under different temperatures

After the static compression molded pulp products shown in Fig. 4. Though the static test, the load-displacement curves was obtained in Fig. 5.



Figure 4 compressed molded pulp products

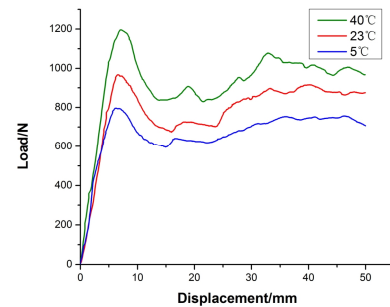


Figure 5 the load-displacement curve of molded pulp products under different temperatures

As is shown in Fig. 5, the static compression curves of molded pulp products under different temperatures were the consistent trend. The curves showed flexion twice, the first flexion deformation caused by the sidewall, and the second is from the bottom cushion flexion deformation of structural units. During the test, when the upper platen contacted the pulp molded article having sidewall deformed to absorb energy, load and displacement increased linearly. When the plate reached a position near fall 6mm the first yield load occur. Then the article load displacement increased with the decrease in displacement 15mm sidewall structure near the article to be crushed. Followed by the bottom of the buffer unit products absorb deformation energy load increases again, and the load and displacement is not linear growth, but stepped rise. In the vicinity of the displacement 35mm, load reached again after the second buckling value presents a step down. When the plate reaches the set height, the test was stop. In the commodity circulation process, molded pulp products as a cushion packaging achieve the purpose of the buffer mainly by deformation of the bottom of the buffer unit. So should make the second buckling load for the design criteria.

Table 4 molded pulp material mechanical properties under different temperatures

Temperature (°C)	The first yield load (N)	The second yield load (N)
5	796.60	753.52
23	960.11	897.73
40	1195.21	1077.17

As table 4 shown, when the temperature is 40°C, the static compressive properties of molded pulp products are relatively good. When the temperature decreased from 40°C to 23°C and 5°C, the first yield load decreased 11.7% and 33.3%, the second yield load decreased 16.7% and 30.0%.

The results show that the temperature has a significant effect on the performance of the static compression of molded pulp products. The reason is that in a certain range, as the temperature increases to reduce the moisture content of the pulp molding material, paper internal moisture reduction, enhanced binding force between fibers, to enhance the strength, elastic modulus of the material is improved. With the elastic modulus of enhanced, the ability to resist deformation improved,

Conclusions

By studying the temperature change on the moisture content of the pulp molding material, the elastic modulus and the overall structure of the static compression performance, some conclusions can be reached.

Temperature has a significant effect on the moisture content of the pulp molding material. Certain humidity, moisture content within a certain range of molded pulp material decreases with increasing temperature, 40 °C when the moisture content is relatively low at 11.87 percent.

Humidity under the same circumstances, when the temperature is 40°C the elastic modulus and ultimate yield strength of molded pulp material is relatively high. When the temperature decreases from 40°C to 23°C and 5°C, the average yield strength decreased 16.0% and 30.1%, the elastic modulus decreased 11.3% and 29.3%.

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