Effects of Different Packing Materials on Cotton Fires

Yanzhao Zhou¹, Wanfu Liu¹, Zhaopeng Ni², Lu Wang³, Bo Gao³

¹School of Mechanical Engineering, Tianjin University of Commerce, Tianjin, China
²Tianjin Fire Reasearch Institute of MPS, Tianjin, China
³China National Cotton Reserves Corporation, Beijing, China
Email: zyztjcu@163.com

Abstract. The aim of this study is to investigate the effects of different packing materials on cotton fires. After the cotton bale is ignited, the caving area, the mass loss rate and the temperature variation of cotton bales were measured. Through the experiment, it was found that Cotton bale packed with Plastic belt has the phenomenon of collapse, but the cotton bale packed with Steel ribbon does not happen to collapse. The mass loss rate of the Cotton bale packed with Plastic belt is faster than that of the cotton bale packed with Steel ribbon, and the temperature is higher.

1. Introduction
Cotton is a renewable energy source, involving agriculture and textile industry. Cotton is closely related to people's life. In recent years, China's cotton fire accident frequently occurs. On July 1st, 2013, a cotton storage in Shanxi province fire burst into flames, burned area of about 10 thousand square meters, about 24 thousand tons of cotton were burned. The safe storage of cotton bales is facing great problems, and the research on cotton fires is imminent.

At present, a lot of research works on the cotton fire have been done by both domestic and foreign researchers, with a focus mainly on the combustion characteristics and effect of environmental factors on combustion of cotton bale, Diane S. Kellogg studied the smoldering process of porous fiber material; it was found that smoldering fabric need enough oxygen and heat [1]. Ohlemiller, through the experimental study of cellulose material combustion to flame change, has been transformed into fire smoldering wind conditions [2]. Darrell, through the study on the effect of different position on the smoldering characteristics of Home Furnishing textiles, obtained the different influence of ignition height on smoldering rate [3]. Based on the study of the spontaneous combustion and smoldering of cotton, the occurrence of spontaneous combustion and smoldering conditions of cotton were obtained by xiaenliang [4]. Wang Qingsong studied the effect of humidity on the spontaneous combustion temperature of cotton [5]. It can be seen from the above that there are few people who study the effects of different packing materials on fire. According to "cotton packaging", we can see that there are two kinds of packing materials for cotton, one is Plastic belt, and the other is Steel ribbon. Based on the cotton fire experiment project, the author studied the impact of different packaging materials on the fire, and explored the appropriate packing materials for cotton.

2. Experimental equipment and experimental method
2.1. **Brief introduction of experimental platform**

The size of this experimental platform is 30m × 6m × 6m.

![Figure 1. Size of experimental platform](image)

The mass loss rate reflects the burning speed of cotton, and it can be estimated by the mass loss rate. The mass loss was measured by using an electronic scale (Model xk3190). The electronic scale had adjustable range with a maximum of 600kg. Its measuring accuracy could also be adjusted, while its minimum accuracy is 0.01kg. The data acquisition instrument used in this study was Agilent 34970A. The data acquisition instrument was connected to a PC and was used to record the temperature measurements in this study. Video equipment DS-2CD3T20D-I3 was used to record the experimental phenomena of the ignition of cotton bales.

2.2. **Test bench layout**

In this experiment, the main test of the cotton caving area, the mass loss rate and the temperature change of cotton package, and use these data to compare the risk of two kinds of tying. The igniter is a cotton swab dipped in 120mL heptane. Cotton rod is cylinder with a diameter of 75mm and a length of 75mm. The camera was arranged on both sides of the fire source. The electronic scale is placed under the cotton bag to measure the mass loss of the cotton bag, The iron plate is placed between the bales and the electronic scales to prevent burning ashes from falling to the ground, as shown in Figure 2. As shown in Figure 3, the size the cotton bag was 1.4m×0.53m×0.7m. A thermocouple was placed on the cotton bag, the distance from the bottom edge is 0.26m.

![Figure 2. Test equipment layout](image)

![Figure 3. Thermocouple position of cotton bale](image)

3. **Experimental phenomena**

The experimental phenomenon of the cotton bale packed with Plastic belt is shown in the Figure 4; the whole experiment is carried out for 40h. After the cotton bale is ignited, the outer surface of the cotton bale carbonized into black. At 1 hours, due to the high temperature when the temperature of
smoldering cotton, steel belt fracture, cotton bag from the center to the two sides fanned out. When the
experiment is carried out to 6h, the high temperature area appears on the surface of the cotton bag by
infrared camera, indicating that the combustion began to be violent at this time. When the experiment
was carried out to 12 hours, the combustion condition of cotton was reached because of the
accumulation of heat, and there was an open flame in the cotton bale. When the experiment was
carried out to the 16 hours flame extinguished, the cotton bale partially collapsed. When the
experiment was carried out to 28h, a large area of bright area was observed by the camera. When the
experiment was carried out to 40 hours, the bales had completely burned.

The experimental phenomenon of the cotton bale packed with Steel ribbon is shown in the Figure5.
The experiment lasted for 55 hours. In the process of the whole experiment cotton kept smoldering. At
13 hours, smoldering occurs relatively slowly, cotton surface became dark, a small amount of flue gas
from bale out. After 28 hours, the surface was covered with a lot of white burning ash. Through the
infrared camera photos can be found in local cotton appear bright phenomenon, show that the position
of high temperature, smoldering burning violently, but also a large amount of smoke. The fire is over
at 55 hours.

It can be seen from the experimental phenomena, steel strapping cotton bale due to the
phenomenon of no collapse, the end of the experiment all cotton fell near the cotton bale, scattered in
an area of about 1500mm × 700mm. Plastic strapping with cotton bale scattered area increased
significantly after the collapse of the bale, where the corresponding area is about 2600mm × 1700mm.
The striping range of the steel strip is 4.2 times more than that of the steel belt. Therefore, spacing
should be considered for the cotton bale storage.

4. Result analysis
4.1. Analysis of mass changes

The mass change curve of the standard cotton bale with different packing materials is shown in the figure 6. According to the graph, the quality loss of cotton packed with plastic steel belt remained stable at the beginning of the experiment; At 13 hours, the loss of quality reached the maximum value of 20kg, analyse the reason that at this time the bales into the fire by smoldering combustion; At 40 hours, cotton complete combustion, the end of the experiment. As shown in Figure 4, the quality of cotton bales packed with Steel ribbon is small; At 30 hours, the mass loss rate of the steel strapping belt reaches the maximum, and the residual cotton bale is 30Kg.

Figure 7 shows the curve of mass loss rate of cotton bale. According to the mass loss rate of cotton bale packed with Plastic belt, at the beginning of the experiment, the mass loss rate of steel belt is stable in 11Kg/h; At 12 hours, with the progress of the cotton surface completely burned, mass loss rate of cotton bale reached the maximum value of 20.4kg/h, until the fuel does not support combustion, mass loss rate began to decline rapidly at 13 hours; At 40 hours, end of the experiment. According to the mass loss rate of cotton bale packed with Steel ribbon, after being ignited, mass loss rate stable at 6kg/h, the burning speed is relatively slow; at 30h cotton residual volume, oxygen volume can maintain the cotton combustion, mass loss rate increases; The combustion ending at 55h. It is known that the cotton bales with different packing materials have a fast burning stage after being ignited by open flame, and the burning speed of the cotton packed with plastic steel belt is faster and more dangerous.

4.2. Analysis of temperature changes

The temperature change at the same point in the two experiments is shown in the figure 8. According to the temperature change of the cotton bales packed with Plastic belt, because of open flame ignition, the temperature is close to 400°C at the beginning of the experiment, the flames extinguished, the temperature quickly reduced; with the test, heat accumulation, reach fire conditions in 6h, temperature rises rapidly; At 7 hours, the temperature reached the highest temperature 398°C; In 8 hours, cotton began to smolder; with the experiment, the heat began to gather again At 12 hours, begin to flame combustion the temperature rising, reaching a maximum of 617°C at 24.4 hours, due to less fuel remaining, the radiation quantity is small, the bale temperature decreased rapidly. According to the temperature change of the cotton bales packed with Steel ribbon, due to keep smoldering state, variation of temperature has little, rapid increase at 3 hours, and reached maximum of 258°C at 5 hours. At 24 hours, the gap between the cotton becomes larger, the oxygen becomes adequate, the combustion becomes violent, and the temperature is rising; At 27 hours, the fuel remains little, and the
temperature begins to drop, the end of the experiment at 55 hours. Therefore, the temperature of flame combustion is higher than the temperature of smoldering.

**Figure 8. Cotton bale temperature change**

5. Conclusions
After the experiment, the Cotton bale packed with Plastic belt collapse phenomenon occurs, and the phenomenon is avoided by the Cotton bale packed with Steel ribbon and the mass loss rate of the Cotton bale packed with Plastic belt bale is about two times as fast as that of the steel ribbon. From the experimental results, the Cotton bale packed with Plastic belt in the fire danger state is greater than Steel ribbon, because the steel belt prone to rupture caused by the spread of cotton in case of fire, cotton porosity increases, from smoldering into flame, and for the storage of cotton bales, it is suggested that the steel ribbon should be packed to reduce the loss of property.

Acknowledgements
Thank you for the China National Cotton Reserves Corporation to provide support.

References
[1] Kellogg, D. S., Waymack, B. E., Mcrae, D. D., Chen, P., Dwyer, R. W., (1998). The initiation of smoldering combustion in cellulosic fabrics. Journal of Fire Sciences, 16(2), 90-104.
[2] Ohlemiller, T. J., (1990). Forced smolder propagation and the transition to flaming in cellulosic insulation. Combustion & Flame, 81(3), 354-365.
[3] Donaldson, D. J., Yeadon, D. A., & Rijr, H., (1981). Smoldering characteristics of cotton upholstery fabrics. Textile Research Journal, 51(3), 196-202.
[4] Xia, E. L., Liu, S. Y., Cheng, X. D., Hou, Y. N., (2013). A comparative study on the characteristic of cotton smoldering and flaming combustion. Fire Safety Science, 22(2), 70-76.
[5] Wang, Q. S., Sun, J. H., Guo, S., (2008). Spontaneous combustion identification of stored wet cotton using a c80 calorimeter. Industrial Crops and Products, 28(3), 268–272.
[6] GB 6975-2013, cotton packaging [S]
[7] Bao, R. L., Zhang, Y., Gu, H. X., (2012). Thermal analysis of risk of spontaneous combustion of cotton. Fire Science and Technology, 2012, 31(1):100-103