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A Study on Thermal Simulation for Adhesive Curing of Cylindrical Cigarettes

Yong-Woo Park*, Seong-Min Moon**, Qi Zhang***, Sung-Ki Lyu**,#

*Department of Convergence Mechanical Engineering, Gyeongsang National University
**School of Mechanical & Aerospace Engineering, Gyeongsang National University
***R&D Department, Zhejiang Shuanghuan Driveline Co., LTD., China

원통형 궐련의 접착제 경화를 위한 열전달 시뮬레이션에 관한 연구

박용우*, 문성민**, 장기***, 류성기**,#

*경상대학교 대학원 융합기계공학과, **경상대학교 기계항공공학부, ***중국 절강쌍환전동유한회사

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ABSTRACT

In this study, cigarettes, which are an essential element in the production of tobacco, are generally not cylindrical. The main materials used for cigarettes are generally hemp and pulp. For the production of cylindrical cigarettes, the cigarettes or cylinders are mounted via gluing. This adhesive is a vinyl acetate emulsion, a high-temperature melt adhesive, and is adhered in a cylindrical shape immediately after being linearly applied to the inner surface of the paper roll or a local part. These adhesives are greatly affected by the atmospheric temperature of the manufacturing space in summer and winter. In the summer, even if the adhesive is temporarily adhered, the coagulation time of the adhesive is long, and problems such as deterioration of the adhesive state occur. in the winter, there is a problem that the temperature of the manufacturing space is low and the adhesive force of the adhesive is poor, resulting in defective adhesive products. In order to solve these problems, another heat transfer device is utilized to cure the remaining adhesive to ensure higher adhesiveness.

Keywords : Cigarette(궐련), Adhesive(접착제), Heat Transfer(열전달), Surface Temperature(표면온도), Internal Temperature(내부온도)

1. Introduction

During manufacturing, cigarettes are rolled into a cylindrical shape through adhesion. The cigarette paper used in the process is mainly composed of hemp and pulp. Adhesives such as vinyl acetate emulsion and hot-melt adhesive are applied linearly on the inner surface or on specific parts of the cigarette paper, and the paper is then rolled into a

Corresponding Author : sklyu@gnu.ac.kr
Tel: +82-55-772-1632, Fax: +82-55-772-1578

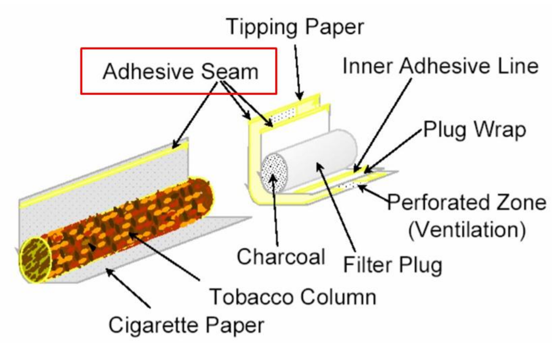
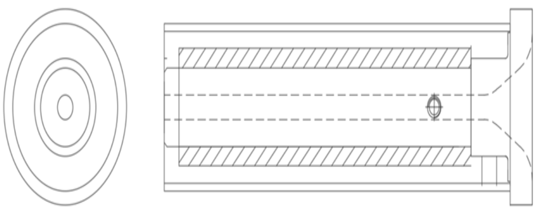


Fig. 1 Composition of cigarettes

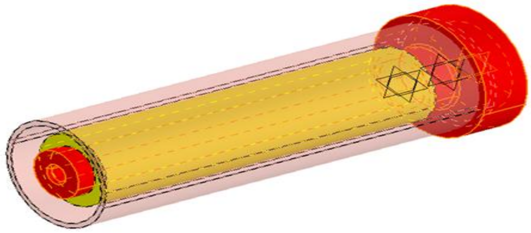
cylindrical shape. The performance of the adhesives used in this process is considerably affected by the ambient temperature of the manufacturing space during summer or winter. Because of the high ambient temperature during summer, the adhesive penetrates the paper and hinders the adhesion. Hence, even if the gluing process is successful, it only lasts for a short time, and the paper is detached due to drying and solidification of the adhesive. In contrast, during winter, the adhesive is weakened due to the low ambient temperature in the manufacturing plant, resulting in defective products with poor adhesion. The components of a cigarette are illustrated in Fig. 1. Several studies have addressed the issues in the cigarette-manufacturing process. Lee[1] investigated the heat and moisture transfer characteristics of a plate heat exchanger made of paper, while Kwon[2] examined the local heat transfer characteristics. Kim[3] reported a decrease in the surface heat transfer coefficient, whereas Yang[4] conducted a study on cooling characteristics. Hence, continuous research efforts have been made to improve the cigarette-manufacturing process[5-10].

2. Design and Modeling

Cigarettes are manufactured at a rate of 8000 ea per minute during the automated manufacturing process. During the rolling of the cigarette paper into a cylinder, an adhesive is applied, followed by the application of heat during the curing process. In the automated manufacturing equipment, a space of 1000mm is appropriate to accommodate the proposed device for efficient heat transfer to the cylindrical cigarettes, which are transported at high speeds. However, it is challenging to secure this additional space within the automated manufacturing equipment. Therefore, a small heat transfer device is included in the middle of the feeding process to address this problem. The device is designed based on (a) 2D drawing and (b) 3D modeling, as shown



(a) 2D drawing



(b) 3D modeling

Fig. 2 Cigarette temperature transmission mechanism design

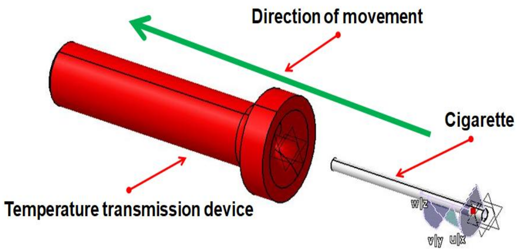


Fig. 3 Cigarette transport direction

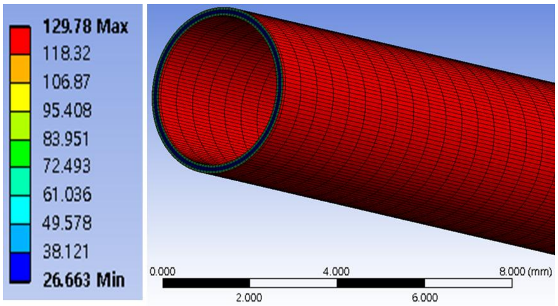
in Fig. 2. The overall setup and direction of the cylindrical cigarette passing through the heat transfer device are shown in Fig. 3.

3. Analysis

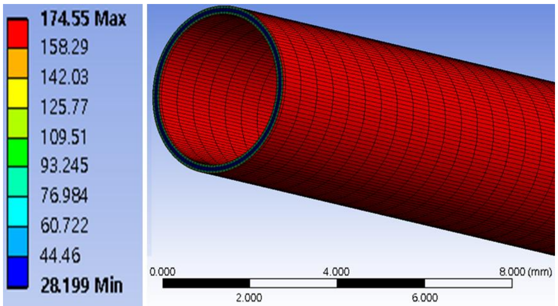
For cylindrical cigarettes, a surface temperature of 300℃ is considered suitable for curing the adhesive. ANSYS is used for heat transfer analysis. The properties of the cigarette paper for the heat transfer analysis are listed in Table 1. The boundary conditions are set as forced convection of air. The heat transfer coefficient is 250 W/m^2 ℃, the initial temperature is 23℃, and the ambient temperatures are set as 500℃, 700℃, 1000℃, 1200℃, and 1300 ℃. With the feeding rate of 8000 ea per minute, the heat transfer analysis is performed by setting the outdoor air exposure time to 0.0075 s for each cylindrical cigarette. The simulation results for heat transfer to the cylindrical cigarette from 500℃ to 1300℃ are presented in Fig. 4.

Table 1 Surface temperature rise trend

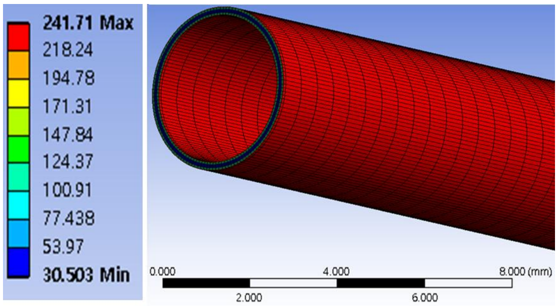
Item	Physical properties
Density(kg/m^3)	120
Thermal Conductivity(W/m℃)	0.05
Specific Heat(J/kg℃)	1338.9



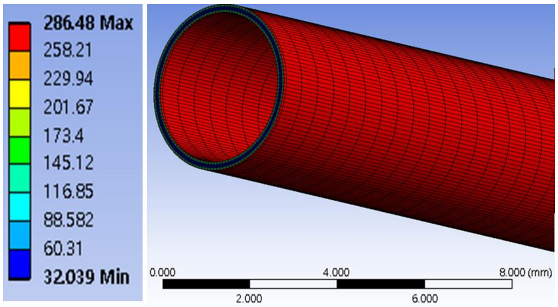
(a) 500 ℃ supply



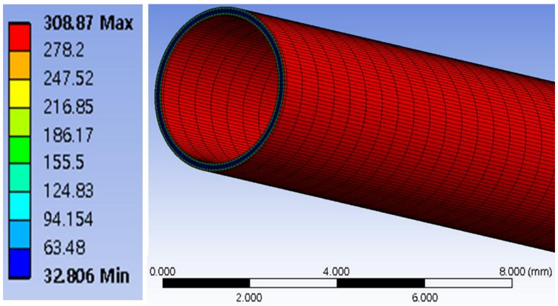
(b) 700 ℃ supply



(c) 1000 ℃ supply



(d) 1200 ℃ supply



(e) 1300 ℃ supply

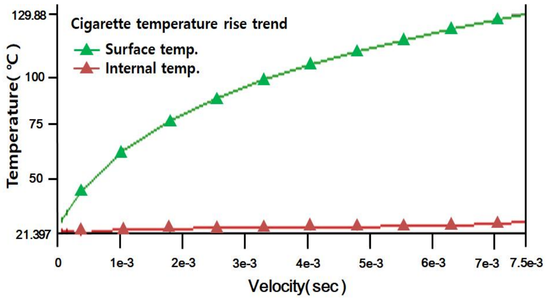
Fig. 4 Cigarette heat supply simulation

4. Results and Discussion

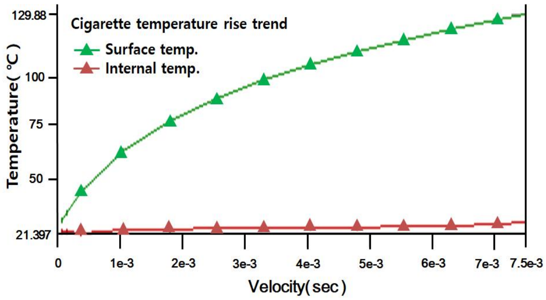
The temperature required for curing the adhesive applied to the cylindrical cigarette is approximately 300℃. The results obtained from the simulations for a feed rate of 0.0075 s with gradual exposure to the different ambient temperatures are as follows: (a) in the case of exposure to ambient air at 500℃, the surface temperature of the cylindrical cigarette is 129.8℃, while the internal temperature is 26.7℃; (b) in the case of exposure to ambient air at 700℃, the surface temperature of the cylindrical cigarette is 174.6℃, while the internal temperature is 28.2℃; (c) for exposure to ambient air at 1000℃, the surface temperature of the cylindrical cigarette is 241.7℃, while the internal temperature is 30.5℃; (d) for exposure to ambient air at 1200℃, the surface temperature is 286.5℃, while the internal temperature is 32.0℃; (e) for exposure to ambient air at 1300℃, the surface temperature of the cylindrical cigarette is 308.9℃, while the internal temperature is 32.8℃. Fig. 5 shows the trends of the temperature increase with respect to the surface temperature(the high-temperature part) and internal temperature of the cylindrical cigarette(the low-temperature part) during manufacturing at a rate

Table 2 Surface temperature rise trend

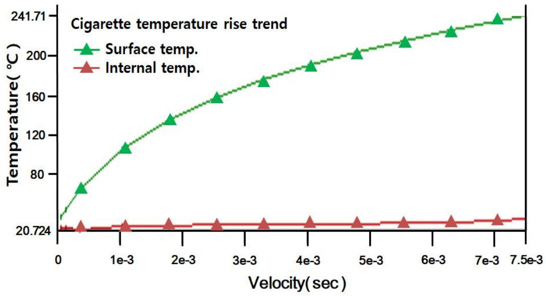
Supply temp. (℃)	Surface temp. (℃)	Internal temp. (℃)
500	129.8	26.7
700	174.6	28.2
1000	241.7	30.5
1200	286.5	32.0
1300	308.9	32.8



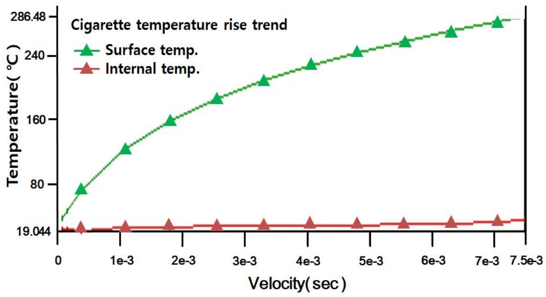
(a) 500 ℃ rise trend



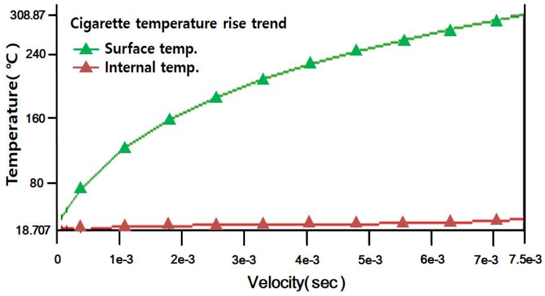
(b) 700 ℃ rise trend



(c) 1000 ℃ rise trend

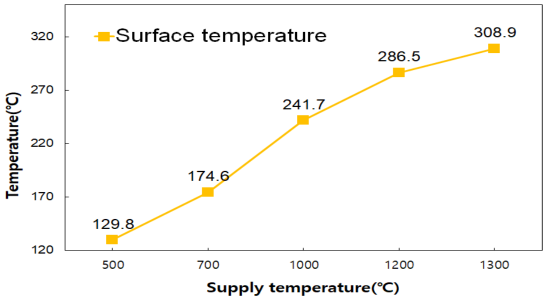


(d) 1200 ℃ rise trend

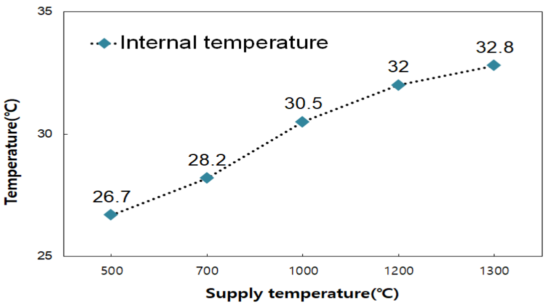


(e) 1300 ℃ rise trend

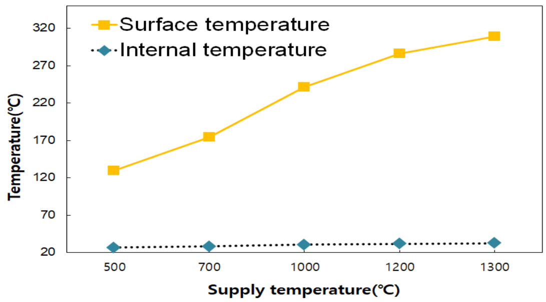
Fig. 5 Cigarette temperature rise trend



(a) Surface temperature rise trend



(b) Internal temperature rise trend



(c) Supply temperature & Internal temperature

Fig. 6 Temperature rise trend

of 8000 ea per minute and a feed rate at 0.0075 s. Fig. 6 shows the trend of the heat transfer to the cylindrical cigarette with respect to the ambient temperature. Fig. 6 (a) presents the trend of the increase of the surface temperature when the applied temperature changes from 500℃ to 1300℃. Fig. 6 (b) presents the trend in the increase of internal temperature when the applied temperature changes from 500℃ to 1300℃. Fig. 6 (c) presents the trend in the increase of the surface and internal temperatures of the cylindrical cigarette when the applied temperature changes from 500℃ to 1300℃. The simulation shows when a cylindrical cigarette is exposed to an ambient temperature of 1300℃ and the heat transfer lasts for 0.0075 s (which is the time required for a single cylindrical cigarette to pass through the feeding path), the surface temperature of the cylindrical cigarette is 308.9℃, and the internal temperature is 32.8℃. Therefore, the simulation confirms that the heat transfer will provide a sufficiently high temperature for the curing of the adhesive on the cigarette.

5. Conclusion

This study was conducted to examine the appropriate temperature required for additional heat transfer to facilitate the curing of the residual adhesive remaining on a cigarette after the manufacturing process, which would otherwise reduce the production of cylindrical cigarettes. It is expected that the proposed method will contribute to increasing in the production of cylindrical cigarettes.

1. In case of exposure to ambient air at 500℃, the simulation showed that the surface temperature was 129.8℃ and that the internal temperature was 26.7℃ for the cylindrical cigarette.
2. In case of exposure to ambient air at 700℃, the simulation showed that the surface temperature was 174.6℃ and that the internal temperature

was 28.2℃ for the cylindrical cigarette.

3. In case of exposure to ambient air at 1000℃, the simulation showed that the surface temperature was 241.7℃ and that the internal temperature was 30.5℃ for the cylindrical cigarette.
4. In case of exposure to ambient air at 1200℃, the simulation showed that the surface temperature was 286.5℃ and that the internal temperature was 32.0℃ for the cylindrical cigarette.
5. In case of exposure to ambient air at 1300℃, the simulation showed that the surface temperature was 308.9℃ and that the internal temperature was 32.8℃ for the cylindrical cigarette.

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