Effect of Connector on Smoke Temperature with Function of Pressing Capsules

Hao Wang, Zhenhua Yu, Han Zheng*, Jianbo Zhan, Geng Li, Ying Zhang, Jiao Xie, Xu Wang, Tingting Yu, Baoshan Yue, Tao Wang, Jiang Yu and Liwei Li
R&D Centre, China Tobacco Yunnan Industrial Co., Ltd, Kunming, Yunnan, 650231, China
Corresponding author’s e-mail: 93320213@qq.com

Abstract. In order to solve the shortcomings of single, fixed and irreplaceable cigarette capsules, the design of connector with function of pressing capsules which can replace and extrude multiple capsules at the same time was carried out, and the influence of this connector on smoke temperature was studied. ISO smoking model was applied to simulate the smoking process, and ANSYS software was used to fit the measured smoke. The geometric models of the smoke channel and the filter were established and meshed respectively. The pressure drop and temperature variation of the connector and the filter were simulated. The simulation results showed that CO and nicotine temperature were in transit. After passing the connector, the temperature drops sharply. When the filter rod reaches room temperature, it proves that the connector achieves the effect of reducing the smoke temperature.

1. Introduction
The technology of "capsule addition" is a molding technology of cigarette filter. In the process of filter production, one or more easy-to-press capsules can be implanted into the filter to achieve the controlled release of special flavors in the process of cigarette smoking, reducing the influence of external environment on the smell absorption and the loss of flavor, which enriches the smoking of cigarettes taste, increasing moisture in the smoking process[1-3]. Most capsules are added to the current products. Some cigarette products can add two capsules to the filter rod of a cigarette, but they require higher processing accuracy and longer filter rods. In order to further incense cigarettes, and at the same time raising the function of moisturizing, reducing coke and reducing hazards in the smoking process of cigarettes, how to select and replace capsules in the smoking process of a cigarette, and how to extrude multiple capsules is an urgent need and trend for the innovative development of capsules[4-6]. A multi-bead rotary extrusion connector and CYO cigarettes were provided in this paper, which solves the problem that the existing technology can not satisfy consumers to choose and press multiple capsules according to their consumption habits. This paper focuses on the influence of connector on smoke temperature.

2. Experimental
The influence of smoke passing through connector and filter on smoke temperature was mainly focused in this paper. The results of simulation are mainly affected by the combustion of cigarette, the structure of connector and the characteristics of filter, especially the combustion process of cigarette has many uncertainties, which is not conducive to the simulation and calculation of the influence of smoking.
passing through connector and filter. In order to simplify the whole simulation calculation, the connector and filter were simulated under standard smoking mode, and the effects of connector and filter on smoke resistance and smoke temperature were simulated.

2.1 Puff mode
According to GB/T 19609-2004, under ISO puff mode, the puff time per mouth is 2 seconds, and the puff capacity is 35 ml per 60 seconds.

ISO puff mode velocity expression: \( v = 0.61 \sin\left(\frac{\pi t}{2}\right) \)

ISO puff mode was used to simulate the simulation, and the puff account was 7.

2.2 Smoking mode and temperature setting
According to the purchased cigarette sample (filter length 30 mm) and the experimental data, cigarettes were smoked seven times under ISO standard smoking mode, and the temperature at the end of each smoking branch was determined.

The maximum temperature at the junction between cigarette and filter after 7 times of smoking is shown in Table 1.

| Puff counts | Temperature     |
|-------------|-----------------|
| 1           | 300K (26.85 °C) |
| 2           | 300K (26.85 °C) |
| 3           | 300K (26.85 °C) |
| 4           | 300K (26.85 °C) |
| 5           | 315K (41.85 °C) |
| 6           | 340K (66.85 °C) |
| 7           | 355K (81.85 °C) |

As the boundary temperature of the first four puff counts is basically the same, the temperature of 300K, 315K, 340K and 355K were selected in the simulation calculation.

2.3 Establishment of connector model and simulation technology route
(a) Establishment and meshing of geometric model of connector smoke passage and filter rod

UG NX three-dimensional software was used to model the connector and filter rod. The model was imported into DesignModeler of ANSYS to extract the smoke passage, and the geometric model of smoke passage through connector was obtained. ICEM was used to mesh the geometric model of the connector passage and filter rod. The structure of the connector is shown in Fig.1.
b) Fluent software simulation of connector and filter model

The standard k-\(\varepsilon\)-double-equation turbulence model, unsteady 3D separation implicit solver and SIMPLE algorithm were applied to simulate Fluent software.

Determine the characteristic parameters of the filter rod
(a) Cellulose acetate fiber is applied to determine its heat transfer coefficient;
(b) The filter is used as a porous medium to determine its porosity;
(c) Determine the inertia resistance coefficient and viscous resistance coefficient of the filter rod.

The smoke is simplified as nicotine (granular phase q) and smoke (gas phase p). The characteristic parameters of smoke are determined, including nicotine density and nicotine particle volume fraction.

ISO suction mode is used in this simulation. The velocity of smoke at the inlet of connector varies with time: \(v = 0.61 \sin\left(\frac{\pi t}{2}\right)\). The corresponding outlet pressure also varies with time. UDF program is used to program the relationship between loading speed and pressure with time. By using Fluent and characteristic parameters of smoke, the characteristic parameters of filter and the temperature of cigarette end were calculated.

In this paper, the connector applied has the function of extruding multiple capsules. The material of the filter is cellulose acetate fiber. The specification of the tow is 3.0Y32000, the circumference is 24.5mm, the length of the filter is 30mm, and the wall thickness of the filter is 0.08mm. UG software is used to model the connector and filter.

3. RESULTS AND DISCUSSIONS

3.1 Smoke resistance and temperature variation of connector and filter

The temperature variation of smoke passing through the connector model and the independent filter during each puff process (2s) was simulated and calculated. The simulation of the independent filter was compared with the connector model as a compared sample. Section selection position is shown in Table 2.

| Filter | Model(connector) |
|--------|-----------------|
| Connector inlet | Z=40.6 |
| Connector center | Z=37 |
| Connector outlet | Z=30 |
| Filter Centre | Z=15 |
| Filter End | Z=7 |
| Filter Front | Z=0 |

Z direction cross-section: mm

Intercept the pressure and temperature data of a certain section in the process of each suction (2 seconds), take the data every 0.2 seconds (there are 10 points in total), make 10 points into a curve, and get the pressure drop change curve and dynamic simulation diagram of pressure drop change of each suction section as well as the temperature change curve and dynamic simulation diagram of temperature change of section smoke. According to the above change curve, the peak value and average value of smoke resistance and temperature of each suction port are obtained. The average value data of four suction temperatures (300K, 315K, 340K and 355K) are made into a curve, and the smoke resistance and temperature change curve of the selected section in the suction process are obtained.

From Fig. 2, it can be seen that at Z = 30, the temperature of CO increases first and then decreases with time at different initial temperatures, but at Z = 15, Z = 7, Z = 0, there is almost no change at different initial temperatures with time, and at Z = 15, Z = 7, Z = 0, the temperatures are almost the same, all of which fall to room temperature. From the above analysis, it is found that after the connector, the temperature has dropped to a certain extent. After the heat exchange process from z = 30 to Z = 15, the temperature of CO has dropped to room temperature.
Fig. 2 temperature of CO at different cross-sections changes with time

From Fig. 3, it can be seen that under different starting temperatures of different cross-sections, the change of nicotine temperature at any time shows a trend of first rising and then falling, which is consistent with the change trend of nicotine puff pressure and puff speed, and is also related to the slow change of nicotine heat exchange rate compared with that of CO. however, with the change from Z= 30 to Z = 0, the trend is getting lower and lower. When z = 0, the trend is as follows: At last, the temperature of nicotine, which starts at different temperatures, drops to room temperature.

3.2 Dynamic simulation cloud chart of temperature change of smoke and nicotine

355k was selected at the inlet, during the suction process of 2s, observe the dynamic simulation cloud chart of the temperature change of smoke and nicotine at different times (0.4s, 0.8s, 1.2s, 1.6s) in the axial direction of connector and filter tip, as shown in Figs. 3- 6. As shown in Fig. 4, the temperature of CO drops sharply after passing through the connector, and the temperature has dropped to room temperature when reaching the filter rod.

As shown in Fig. 5, in the first 0.4 s, as soon as the smoke enters the filter tip, it immediately transfers heat with acetate fiber, which greatly reduces the temperature of nicotine in the smoke and increases the temperature in the filter tip. Nicotine flows into the filter tip in a cone shape, and the temperature changes in a cone shape. The centre temperature is the highest, and it decreases along the radial direction. At 0.8 s, the smoke continues to enter the filter but has not completely penetrated the filter, the nicotine temperature continues to drop, and presents stratification phenomenon. At 1.2s, the smoke continues to diffuse to the suction end through the filter tip, and heat transfer occurs in the filter tip, and the nicotine temperature continues to drop.

Fig. 4 CO temperature distribution (x = 0) (t=0.4s, 0.8s, 1.2s, 1.6s)

Fig. 5 Nicotine temperature distribution (x = 0)(t=0.4s, 0.8s, 1.2s, 1.6s)
As shown in Fig. 6, the temperature of CO drops sharply after passing through the connector, and the temperature drops to room temperature when reaching the filter rod.

![Fig. 6 Temperature distribution of CO in different sections (Z=0mm, Z=7mm, Z=15mm, Z=30mm)](image)

As shown in Fig. 7, the nicotine temperature drops sharply after passing through the connector, and when it reaches the suction end of the filter rod, the temperature has dropped to room temperature.

![Fig. 7 Temperature distribution of nicotine in different sections (Z=0mm, Z=7mm, Z=15mm, Z=30mm)](image)

4. Conclusion
(1) At z = 30, at different initial temperatures, the temperature of CO increases first and then decreases with time, but at z = 15, z = 7, z = 0, there is almost no change at different initial temperatures with time, and at z = 15, z = 7, z = 0, the temperature of CO decreases to room temperature. This shows that after the connector, the temperature has dropped to a certain extent. After the heat exchange process from z = 30 to Z = 15, the temperature of CO has dropped to room temperature.

(2) At different starting temperatures of different cross-sections, the change of nicotine temperature at any time and time presents a trend of first rising and then falling, which is consistent with the change trend of nicotine suction pressure and suction speed, and is also related to the slow heat exchange rate of nicotine compared with that of CO.

(3) In the first 0.4 s, as soon as the smoke enters into the filter, it immediately transfers heat with acetate fiber, which greatly reduces the temperature of nicotine in the smoke and increases the temperature in the filter. Nicotine flows into the filter tip in a cone shape, and the temperature changes in a cone shape. The centre temperature is the highest, and it decreases along the radial direction. At 0.8 s, the smoke continues to enter the filter but has not completely penetrated the filter, the nicotine temperature continues to drop, and presents stratification phenomenon. At 1.2s, the smoke continues to diffuse to the suction end through the filter tip, and heat transfer occurs in the filter tip, and the nicotine temperature continues to drop.

(4) The temperature of CO and nicotine drops sharply after passing through the connector, and the temperature drops to room temperature when reaching the filter rod, which proves that the connector has the effect of reducing the smoke temperature.

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