Research on infrared property of spinning materials

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Keywords: Infrared property; Spinning materials; Fibre structure

Abstract. Spinning materials almost belong to high polymer material, which have three kinds of phenomena below: reflection, projection and absorption. Due to the particularity of fibre structure, radiation incident to the fibre radiation occurs the multiple internal reflection as well as the transmission and absorption of part of radiation.

Introduction

Regarding spinning material as a uniform thickness of isotropic ideal fabric. As shown in figure 1, we suppose a beam of infrared radiation exposure on the strength of the single-layer ideal fabric for I_0 ; the incidence and reflection will occur when I_0 arrived at the leading edge of the fabric; then through the fabric itself, Incident infrared ($I_{Li}=I_1$) arrives at trailing edge, and the part of the energy is absorbed. As a result, the intensity attenuates to I_2;setting for the attenuation coefficient, I_2 occurs reflection and transmission in fabric trailing edge, whose reflected light intensity is I_3; and when I_3 reaches the front fabric, the intensity attenuates to I_4, I_4 carries on the transmission and reflection in front fabric edge , and so on.

Total intensity of infrared transmission of single-layer ideal fabric (I_{1T}):

$$I_{1T}=（I_{1i}e^{-\mu d}+I_{1i}e^{-\mu d}\alpha_{R2}\,e^{-\mu d}+I_{1i}e^{-\mu d}\alpha_{R2}e^{-\mu d}\alpha_{R2}e^{-\mu d}+\ldots\ldots）\alpha_{T2}$$

$$=I_{1i}\sum_{n=0}^{\infty}\alpha_{R2}^{n}e^{-(n+1)\mu d}\alpha_{T2} \qquad (1)$$

Where I_{1i} means the infrared radiation intensity of ideal I_0 into single-layer fabric,that is: $I_{1i}=(1-\alpha_{R1})I_0$;

Where α_{R1} stands the reflectivity of Infrared radiation from the air to the single layer fabric ideal interface ;

Where α_{R2} is the reflectivity of infrared radiation from single ideal fabric reflectivity to the air interface;

Where α_{T1} is the transmittivity of Infrared radiation from single ideal fabric to the air interface.The relationship is shown in figure 2.

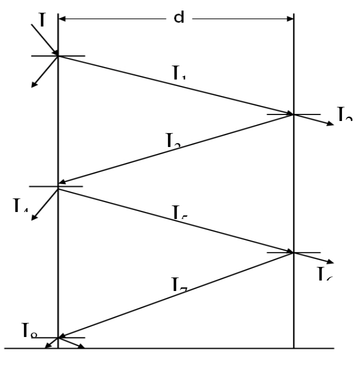

Fig. 1 the reflection and transmission of infrared radiation in single-layer ideal fabric

Total reflection intensity（I_{1R}）of single-layer ideal fabric as follows[1]:

$$I_{1R}=I_0\alpha_{R1}+I_{1i}(e^{-\mu d})\alpha_{R2}(e^{-\mu d})+I_{1i}(e^{-\mu d})\alpha_{R2}(e^{-\mu d})\alpha_{R2}(e^{-\mu d})\alpha_{T2}+\ldots\ldots$$

$$=I_0\alpha_{R1}+I_{1i}\sum_{n=0}^{\infty}(e^{-\mu d})^{2n+2}\alpha_{R2}^{2n+1}\alpha_{T2} \qquad (2)$$

And,$I_{1i}=\alpha_{T1}I_0$

Where α_{T2} means the transmittivity of infrared radiation from single-layer ideal fabric to the air interface;

the total absorption intensity of single-layer ideal fabric (I_{1R}) :

$$I_{1A}=I_{1i}（1-e^{-\mu d}）+I_{1i}\alpha_{R2}(1-e^{-\mu d})+I_{1i}(e^{-\mu d})\alpha_{R2}(1-e^{-\mu d})+\cdots\cdots$$

$$=I_{1i}(1-e^{-\mu d})\sum_{n=0}^{\infty}(e^{-\mu d}\alpha_{R2})^n\ \alpha_{T1} \qquad (3)$$

Defining the total transmittance (α_{1T}), total emission rate（α_{1R}） and total absorption（α_{1A}）of single-layer ideal fabric, as below:

$$\alpha_{1A}=I_{1A}/I_0=I_{1i}（1-e^{-\mu d}）\sum_{n=0}^{\infty}(e^{-\mu d}\alpha_{R2})^n/I_0=\alpha_{T1}（1-e^{-\mu d}）\sum_{n=0}^{\infty}(e^{-\mu d}\alpha_{R2})^n$$

(4)

$$\alpha_{1R}=I_{1R}/I_0=I_0\alpha_{R1}+I_{1i}\alpha_{T2}\sum_{n=0}^{\infty}(e^{-\mu d})^{2n+2}\alpha_{R2}^{2n+1}/I_0$$

$$=\alpha_{R1}+（1-\alpha_{R1}）\alpha_{T2}\sum_{n=0}^{\infty}(1-e^{-\mu d})^{2n+2}\alpha_{R2}^{2n+1} \qquad (5)$$

$$\alpha_{1T}=I_{1T}/I_0=I_{1i}\sum_{n=0}^{\infty}\alpha_{R2}^{n}e^{-(n+1)\mu d}\alpha_{T2}/I_0=（1-\alpha_{T1}）\alpha_{T2}\sum_{n=0}^{\infty}\alpha_{R2}^{n}e^{-(n+1)\mu d}\alpha_{T2}$$

(6)

By the law of conservation of energy ,we know that:

$$I_{1T}+I_{1R}+I_{1A}=I_0;\quad A_{1T}+\alpha_{1R}+\alpha_{T1}=1 \qquad (7)$$

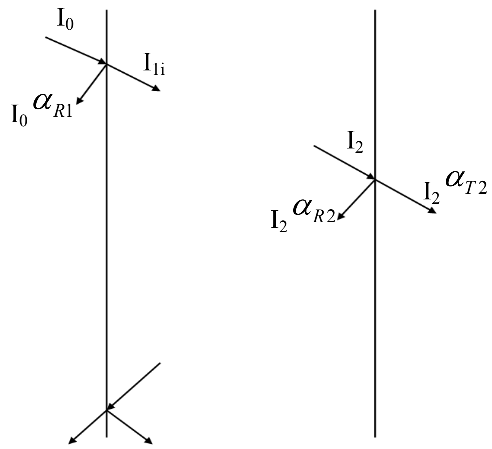

Fig. 2 In optical medium and air cushion interface

Infrared radiation in the multilayer ideal fabric materials

When ideal fabric for layer or multilayer stack together, air layer will certainly exists between fabrics, and the reflection and transmission of the infrared radiation between fabrics will have a influence on Multi-layer fabric overall reflection and transmission . the reflection and transmission between fabrics as shown in figure 3:

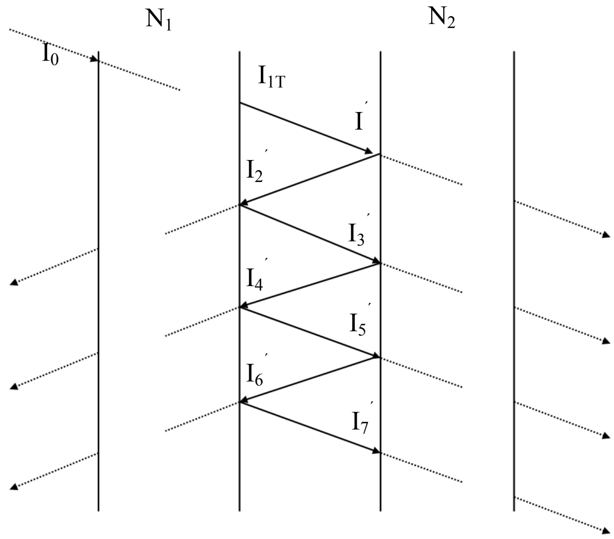

Fig. 3 infrared radiation in multilayer reflection and transmission between the ideal fabric

Two layers of fabric, for example, the transmission intensity (I_{1T}) of the first layer (N_1), into the double layer fabric, occurs reflection and transmission . The intensity of the I_{1T} on the surface of the second floor fabric (N_2) is I_1. I_1 carries on the reflection and transmission on N_2 surface, and its reflection components (I_2) will also appear reflection and transmission on layer N_2,and so on. Therefore before incident to the layer N_2, the total transmission intensity (I_{02}) is as follows:

$$I_{01}= I_{1T}\alpha_{1R} + I_{1T}(\alpha_{1R})^3 + I_{1T}(\alpha_{1R})^5 + I_{1T}(\alpha_{1R})^7 + \cdots = \frac{\alpha_{1R}}{1-\alpha_{1R}^2} I_{1T} \quad (8)$$

Where α_{1R} stands for the reflectivity of the infrared beam from the air to single-layer ideal fabric interface.

At the rear of the layer N_1, the total reflection intensity produced by layer N_2 (I_{01}) as follows:

$$I_{01}= I_{1T}\alpha_{1R} + I_{1T}(\alpha_{1R})^3 + I_{1T}(\alpha_{1R})^5 + I_{1T}(\alpha_{1R})^7 + \cdots = \frac{\alpha_{1R}}{1-\alpha_{1R}^2} I_{1T} \quad (9)$$

On these grounds ,we can take infrared radiation in the double layer fabric whose transmission intensity is I_{02} and reflection intensity is I_{01} for the radiation in the single layer N_2, so we can conclude:

transmission intensity : $I_{NT}= \alpha_{1T} I_{0n}^{(n-1)} = \alpha_{1T}\left[\frac{I_{(n-1)T}}{1-\alpha_{1R}^2}\right] = \frac{\alpha_{1T}^n}{\left(1-\alpha_{1R}^2\right)^{n-1}} I_0$

reflection intensity: $I_{2R}=I_{1R}+\alpha_{1T}\, I_{01}= I_{1R}+\frac{1}{1-\alpha_{1R}^2} I_{1T} = I_{1R}+\frac{\alpha_{1R}\alpha_{1T}^2}{1-\alpha_{1R}^2} I_0 = I_0\alpha_{1R}\left(1+\frac{\alpha_{1T}^2}{1-\alpha_{1R}^2}\right)$

absorption intensity : $I_{nA}=I_{(n-1)A}+\alpha_{1A} I_{0n(n-1)}+\alpha_{(n-1)A} I_{0n(n-1)}$

$= I_{(n-1)T}+\alpha_{(n-1)A}\frac{1}{1-\alpha_{1R}^2}+I_{(n-1)T}\frac{\alpha_{1R}}{1-\alpha_{1R}^2} = I_{(n-1)A}+ I_{(n-1)T}\frac{\alpha_{1A}+\alpha_{(n-1)A}\alpha_{1R}}{1-\alpha_{1R}^2}$

$$=I_0[\alpha_{(n-1)A}+\alpha_{(n-1)T}\frac{\alpha_{1A}+\alpha_{(n-1)A}\alpha_{1R}}{1-\alpha_{1R}^2}]$$

where $I_0^{n(n-1)}$ is the total radiation intensity in the leading edge of layer N_n ;

where $I_0^{(n-1)(n-1)}$ is the radiation intensity in the the trailing edge layer $N_{(n-1)}$ by the reflection in layer N_0.

The influence factors of spinning material infrared

Spinning material moisture regain effects on infrared

Spinning materials can absorb the moisture in different degree, and the absorption ability of natural fibres(such as cotton, wool, hemp, silk, etc.) is stronger. While, moisture absorption ability of chemical fibres have a huge difference depending on the different chemical composition. In general, the moisture absorption ability of polyester and polypropylene fibre is poorer, while the ability of eyes nylon and polyamide fibre is stronger; fibre has a great influence on not only its mechanical properties but also the electrical and optical properties after moisture absorption. Since the moisture has strong absorption ability to infrared radiation within a certain band area, the total reflectance, transmittance and absorption rate of infrared radiation on the surface of the fabric will change when the infrared radiation exposure to moisture regain of different surface of the fabric. Water in some infrared wave band will appear strong absorption band, and its peak wavelength of absorption band is about 0.94 μ m, 1.2 to 1.5 μ m, 1.8 to 2.0 μ m, 2.5 to 3.1 μ m and 4.8~7.7 μ m, in which around 3.0 μ m is the strongest absorption.

Spinning material color absence affects on infrared radiation

Colour refers to the colour at visual band of transmitted or reflected by objects (380~780 microns) .the colour will affect the absorption of different wavelengths light reflection and transmission. The influence of the fabric colour at infrared wavelengths is not corresponding with that at the visible light wave band. Through test, we found the same sample but of different colour lead to the great difference in transmission rate ,the infrared transmittance in the white sample is over two times higher than that in the black sample, and the infrared transmittance in the white sample presents the evident tendency of decrease along with the increase of dominant wavelength infrared , namely of far-infrared transmission capacity is weak to the spinnings; while infrared the evolution of the transmissivity in black sample is not significant. in conclusion, the surface of the dark colour has strong absorbency to infrared radiation, and colour have strong absorption to relatively short wavelengths of infrared wavelengths.

Degree of Spinning vacuum affects on infrared radiation

Atmosphere can attenuate the intensity of uv and visible light, meanwhile, absorb infrared radiation, leading to the intensity attenuation. In numerous factors, which affect the spinning material absorb the infrared, the density of air significantly play an crucial part[2] .

Through sample study we found: radiation has a certain difference in air and vacuum conditions, similarly, conduction and convection heat radiation has a certain differences. Under the condition of different atmospheric density, the absorption rate of atmosphere differs to infrared radiation. Vacuum had a greater influence on the radiation performance for fabric : the greater the radiation intensity, the faster the gas heats up, and atmospheric absorption rate will decrease, influence on radiation performance fabric decreases accordingly.

Conclusion

Infrared stealth technology is to reduce the target detestability, of making it difficult to detect. The infrared stealth technology usually include three aspects: infrared radiation characteristic of target, to reduce the infrared radiation intensity of the target and to change the way of the infrared radiation transmission of the target . Infrared stealth spinning materials mainly is made through the anti-infrared coating, also through the dyeing for infrared stealth effect in recent years. Coating means a mixture of several kinds of paint and adhesive grinding paste paints on the fabric surface with high temperature curing endue to achieve the properties of infrared reflection, absorption and infrared emissivity are as basically identical as the natural environment. dyeing spinning materials in recent years, are studying as a new technology, there are not a few dye with the absorption characteristics to the infrared and are mostly used in the field of optoelectronic functional material. the dyed fabric which satisfy the requirement of infrared stealth is still under study.

References

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[2] Li Heng. *Color technology principle and its application [M]*. Beijing: science press. 1994.