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MARKET COMPETITION AND RISK ASSESSMENT OF NANOFIBER COMPOSITE MATERIALS

Competencia de mercado y determinación del riesgo de materiales con compuestos de nanofibras

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Key words: nanofiber composite materials, risk assessment, market competition, nano cellulose.

ABSTRACT

Nano cellulose has the advantages of high degree of polymerization, high strength, degradability, and large specific surface area. The modifier is uniformly dispersed in the matrix material to form a composite system containing nano-scale materials in one phase. With regard to the above-mentioned competitive situation of performance fibers, China should first strengthen the research on engineering scale-up, focusing on finding the factors that affect product quality and dispersion coefficient from engineering issues, and making continuous improvements. Using the analytic hierarchy process method, according to the idea of first decomposition and then synthesis, through pairwise comparison between risk indicators, the risk weights of risk factors at various levels in the risk assessment index system are rigorously calculated and sorted, and the degree of membership and validity are compared. The risk assessment index is judged, the fuzzy clustering algorithm is used to identify the bad data in the market competition data, and the conditional value-at-risk (CVaR) model is constructed to conduct risk assessment. Experimental results show that the actual logarithmic rate of return fluctuates around 0, most of which are higher than the Va R value. Only in extreme cases will it break the Va R curve; the accuracy of risk assessment is close to 100%, and the (Tech-Sector Volatility)TSV indicator begins to decline significantly. That is, the transmission sensitivity of risk data is effectively improved.

Palabras clave: materiales compuestos de nanofibras, determinación del riesgo, competencia de mercado, nanocelulosa.

RESUMEN

La nano celulosa tiene las ventajas de un alto grado de polimerización, alta resistencia, degradabilidad y gran superficie específica. Un modificador se dispersa uniformemente en el material de la matriz para formar un sistema compuesto que contiene materiales a nanoescala en una sola fase. Lo mencionado es parte de la situación competitiva de las fibras de rendimiento. China debe primero fortalecer la investigación sobre la ampliación de la ingeniería, centrándose en encontrar los factores que afectan la calidad del producto y el coeficiente de dispersión de las cuestiones de ingeniería, y hacer mejoras continuas. Utilizando el método de proceso de jerarquía analítica, de acuerdo con la idea de primera descomposición y luego síntesis, a través de la comparación por pares entre los indicadores de riesgo, se calculan y clasifican rigurosamente las ponderaciones de los factores de riesgo en los distintos niveles del sistema de índices de evaluación de riesgos, y se compare el grado de pertenencia y validez. Se evalúa el índice de evaluación del riesgo, se utiliza el algoritmo de agrupación difusa para identificar los datos negativos en los datos de competencia del mercado, y se construye el modelo de valor condicional en riesgo (CVaR) para llevar a cabo la evaluación del riesgo. Los resultados experimentales muestran que la tasa logarítmica real de retorno fluctúa alrededor de 0, la mayoría de los cuales son más altos que el valor Va R. Sólo en casos extremos se romperá la curva Va R; la precisión de la evaluación del riesgo es cercana al 100% y el indicador TSV (Tech-Sector Volatility) comienza a disminuir significativamente. Es decir, se mejora efectivamente la sensibilidad de transmisión de los datos de riesgo.

INTRODUCTION

In recent years, with the accelerated progress of nanofiber technology and commercialization, more and more manufacturers have invested in the application research and market development of nanofibers (Ogawa et al. 2019). The emergence of functionalized nanofibers has attracted increasing attention. Nano-composite materials are the composite of nano-particles and nano-particles, nano-particles and conventional blocks, and further develop into composite nano-films. The exploration of the synthesis and physical properties of nanocomposites became the leading direction of this stage of research. The synthesis of artificially assembled nanostructured material systems has attracted more and more attention and is becoming a hot spot in nanomaterials research. Using PBI nanofibers and epoxy resin to make reinforced composite products, greatly improves its performance when compared to conventional polybenzimidazole (PBI) fiber/epoxy resin reinforced composite materials (Yang et al. 2019, Sheng et al. 2021,). For example, the Young's modulus of PBI nanofiber/rubber (SBR) reinforced composite is 10 times that of ordinary PBI fiber/rubber (SBR) (Abdul-Rahman et al. 2018). The emergence of nanomaterials heralds the quiet arrival of a new nano era. The arrival of the nano era is not only an opportunity but also a challenge for China. Compared with other advanced developed countries, the basic research level of nanomaterials technology in China is not much different. In some aspects, it is even a world leader, but there is a certain gap in industrialization. We must avoid repeating the mistakes of computer technology and superconducting technology (Kollander et al. 2019).

Nanocellulose (CNF) is the smallest physical structural unit of cellulose, which refers to fibers with a diameter between 1 nm and 100 nm (Fig. 1). It has the advantages of high degree of polymerization, high strength, degradability, and large specific surface area (Bijlsma et al. 2018). As competition in the nanocellulose industry continues to intensify, companies are paying more and more attention to in-depth research on the market. Especially the research on the development trend of the market and the development environment of various enterprises in the next few years, in order to take effective measures in advance to deal with emergencies in the market.

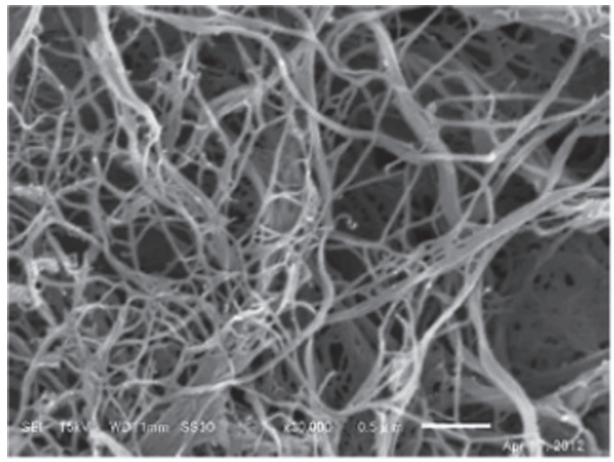

Fig. 1. Nanocellulose (CNF).

China has conducted research in the field of nanofibers for many years. Research institutes and institutions of higher education in Shanghai, Changchun, Beijing, Suzhou and other places have achieved considerable research in the forming and application of nanofibers, but overall, it is still in the laboratory stage (Drygala et al. 2019). In recent years, many foreign manufacturers have realized the commercialization of nanofiber technology, especially the electrospinning nanofiber production line that Elmarco Company put on the market, which fully demonstrates that the research and development cycle of new materials in the world has been significantly shortened (Zhu et al. 2019, Hu et al. 2021). How to keep up with the development of nanofibers, a frontier field, is very important for countries with the largest global fiber output. With the progress of domestic nanofiber forming technology and the deepening of application research, the consumption research of nanofibers should also be put on the agenda (Ishikawa and Shibata 2019). The hazards of nanofibers to humans are not yet fully understood. Information from the Sino-British International Symposium on "Nanotechnology Monitoring and Innovation" forum in February 2021 shows that domestic companies, including scientific and technical personnel from certain research institutes, are concerned about nanotechnology. The awareness of potential risks and prevention is far from insufficient. Facing the new century with the rapid development of new technologies, the health and environmental problems that may be brought about by the development of new materials are not only numerous but also difficult to deal with (Feng et al. 2020, Ning et al. 2021). Therefore, practitioners should be vigilant to the possible hazards in the development of nanofiber technology and should not ignore the risk research in the application of nanofibers.

This paper presents research on market competition and risk assessment of nanofiber composite materials using an analytic hierarchy process (AHP). This methodology can divide various factors in complex problems into interrelated and orderly levels to make them organized. According to the subjective judgment structure of certain objective reality, it can directly and effectively combine the expert opinions with the objective judgment results of analysts, quantitatively describe the importance of pairwise comparison of elements at one level, and improve the accuracy of evaluation. Therefore, using the AHP method, according to the idea of decomposition first and then synthesis, through pairwise comparison between risk indicators, the risk weight of each level of risk factor in the risk assessment index system is rigorously calculated and sorted. The risk assessment index is judged according to the degree of membership and validity, the fuzzy clustering algorithm is used to identify the bad data in the market competition data, and the CVa R conditional value-at-risk model is constructed to conduct risk assessment.

High risk is one of the most important characteristics of the nanomaterials industry. Most of the technologies involved in the nanomaterials industry are at the forefront of contemporary science and technology (Viloria Avila et al. 2020). Therefore, the nanomaterials industry is a risk industry, which is significantly higher than the general industry (Sassi and Toumi 2018). Its high risk should be manifested in the following aspects:

(1) Technical risk. Due to the complexity of nanomaterial development and research, technology development faces various uncertain factors, such as technical difficulties, achievement maturity, gap with commercialization, development cycle and technology life span. In particular, nanotechnology is mostly in the foreword of contemporary science and technology and has obvious characteristics of advancement. It is difficult to determine the probability of success in the transformation of research results into industrial production and new products.

(2) Market risk. It takes one year for nanomaterials products from research and development to trial production and mass production until they generate benefits. It takes a year or even longer for the long ones. During this period, the situation may undergo unpredictable changes. If the product cannot meet the requirements of the market, or a newer and more advanced product is introduced to replace it, the early research and development investment will become an unprofitable investment and bring losses to investors.

(3) Capital risk. With the deepening of the development stage of nanomaterials production enterprises, the demand for funds will increase rapidly. On the other hand, there are few financing channels for nanomaterials research and development, so it is easy to have a financial supply fault at a certain stage of nanomaterials research and development. Nanomaterials companies are likely to be out of lack of funds. It is difficult to make turnover and lack the ability to pay. Because of the objective existence of these risks, many nanotechnology financing activities ended in failure. According to relevant statistics, more than half of the investment in the nanomaterials industry cannot get a normal return.

(4) Manage risks. If the managers of nanomaterials manufacturing enterprises are technical experts who are better at technology than management, the possibility of failure may increase due to poor management.

Based on the global nanocellulose market, North America has the largest market share due to technological leadership and strong demand for environmentally friendly materials. At present, North America and Europe are still in the spreading stage of the COVID-19 pandemic. Although the market demand is declining, it still has greater market resilience. It is expected that market demand will increase during the review period after the epidemic has improved. The Asia-Pacific region has the highest compound annual growth rate (Chaudhary et al. 2020). Due to the increase in the middle-class population, the increase in demand for new energy vehicles, the continuous advancement of technology and the cheap manufacturing costs, it is expected to promote market growth.

In the face of the above-mentioned competitive situation of the world's major high-performance fibers, China should first strengthen engineering scale-up research, focusing on engineering issues to find factors that affect product quality and dispersion coefficient, and continuously improve, and on this basis, expand production capacity according to market demand. It reaches economic scale and realizes serialization of products.

Market risk assessment

This article mainly uses the AHP method, according to the idea of decomposing first and then integrating, through the pairwise comparison between risk indicators, the risk weight of each level of risk factor in the risk assessment index system is rigorously calculated and sorted (Delgado 2019). The detailed application idea is shown in **figure 2.**

The analytic hierarchy process is used to deal with the risk of competition in the composite material market. Different market competition risk factors have different risks to the composite material market. In order to reflect the relative importance of each factor, it is dealt with accordingly (Li et al. 2019). The steps for handling risk factors are as follows.

Step 1: Building a hierarchical structure model.

In order to conduct in-depth research on the relationship between factors, the evaluation questions must be organized by dividing the relevant factors into layers based on attributes, and corresponding structural models built on this basis (Byun et al. 2018). Finally, the first layer is the target layer; the middle layer is the criterion layer, and the lowest layer is the scheme layer.

Step 2: Constructing the judgment matrix.

Assuming that A is a certain level of target, the index of the next level is represented as B_i, B_j ($i, j = 1,2,\cdots,n$) and A is the criterion, then B_{ij} represents the relative importance value of B_i to B_j, and the judgment matrix composed of B_{ij} is:

$$P = \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1n} \\ B_{21} & B_{22} & \cdots & B_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ B_{n1} & B_{n2} & \cdots & B_{nn} \end{bmatrix} \tag{1}$$

Step 3: Calculating the importance ranking.

According to the judgment matrix P, the importance of the indicators is ranked as:

$$P\omega = \lambda_{max}\omega \tag{2}$$

Among them, λ_{max} represents the largest feature root of the judgment matrix P; ω represents the feature vector corresponding to the largest feature root.

Step 4: Consistency checking.

It is necessary to check the consistency of the importance ranking obtained above. The consistency test is mainly to calculate the consistency index CI, and its calculation formula is expressed as:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3}$$

Among them, n represents the number of risk factors.

The subordinate investigation is mainly to screen the evaluation indicators that can better reflect the market competition and risk assessment of nanofiber composites by judging the importance of risk assessment indicators to their previous risk factors. The subordinate investigation is based on the expert survey method, and the importance of risk assessment

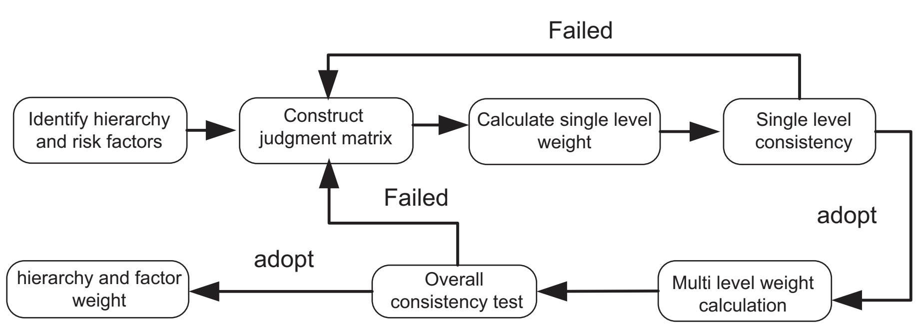

Fig. 2. Thoughts on the application of AHP in risk assessment.

indicators is divided into five levels in descending order of importance. They are “very important”, “important”, “generally important”, “not important”, and “not important at all”. And set the number of times the expert selects “important” and “very important” as the selected number.

First, experts vote for the importance of each risk assessment index compared to the risk factors of the previous level, and then count the results of the voting. The ratio of the number of expert selections divided by the total number of effective expert selections (retaining three decimal places) is used as the degree of membership to reflect the importance of each index. The calculation formula of membership degree is as follows:

$$R_i = \frac{A_i}{A_{total}} \tag{4}$$

In the formula, R_i represents the degree of membership of the risk assessment index, A_i represents the number of expert selections, and A_{total} represents the total number of effective expert selections.

R_i = 0.3 must be set as the screening threshold, the index kept as $R_i > 0.3$, and values of $R_i \le 0.3$ eliminated.

The definition of validity in statistics refers to the degree of correlation between a measurement result and an external standard. The higher the degree of correlation, the higher the validity, and vice versa (Li et al. 2020). This paper chooses the method of validity test in order to screen out the risk assessment indicators that are highly related to the risk factors of the upper level and can well represent the risk content of the upper level.

Different test methods are generally selected for different validity. The measurement of the risk assessment index system for residential development projects of Chinese developers in Australia belongs to the content validity, and such validity is often evaluated by the empirical judgment method. Therefore, the validity test of this round is mainly based on the expert survey method, and the empirical judgment method is used to test the validity of the risk assessment indicators. By inviting relevant experts in the evaluation team to judge the validity of risk assessment indicators based on their rich experience.

The commonly used content validity ratio (CVR) formula is:

$$CVR = \frac{n_a - \frac{n}{2}}{\frac{n}{2}} = \frac{2n_a}{n} - 1 \tag{5}$$

In the formula, n represents the number of effective assessment experts, and n_a represents the number of assessment experts who believe that a certain risk assessment index is a good representation of the risk content of the previous level. That is to say, among the evaluation experts, the number of representatives with “medium” and “high” is selected. The value range of CVR is [-1, 1]. The larger the value, the higher the validity of the index system.

CVR = 0.6 must be set as the critical value and values of $CVR < 0.6$ eliminated.

The fuzzy clustering algorithm is used to identify the bad data existing in the market competition data. In the process of identifying the bad data, the difference between the measured data ΔZ and the standard residual R_N at the collection time of two adjacent samples is selected. This is used as the feature value of the fuzzy clustering operation to obtain the original sample data set. Standardized deviation processing on the characteristic index matrix containing the measured data difference ΔZ and the standard residual R_N is performed. The calculation formula is as follows:

$$X'_{ij} = \frac{X_{ij} - \overline{X_i}}{\sqrt{\sum_{j=1}^{R_N} \left(X_{ij} - \overline{X_j}\right)^2 \Delta Z}} \tag{6}$$

Among them, X_i and X_j are the measurement data of two adjacent sample collection moments; X_{ij} is the characteristic index; X'_{ij} is the characteristic index matrix.

The fuzzy clustering algorithm is used to cluster the characteristic index matrix after the standardized deviation processing, and the clustering of the sample set under different cluster numbers is obtained. The COS (cosine) clustering effectiveness index is used to determine the number of clusters. In order to obtain the best clustering result of the feature index matrix, the criteria for determining the number of clusters using the COS clustering effectiveness index are as follows:

$$COS = \frac{C+S}{O} = \frac{\sum_{i=1}^{C}\left(\max\left\|X_j - X_i\right\|\right) + \min\left\|X_i\right\|}{\sum_{j=1}^{C}\sum_{S} 0_{ij}} \tag{7}$$

Among them, C, S, and O are the three-clustering metrics of the COS clustering effectiveness index. The larger the value of this index, the more accurate the result of fuzzy clustering division will be.

Therefore, the number of clusters corresponding to the maximum value of this index is the optimal number of fuzzy clusters of the feature index matrix.

CVa R, also known as the Conditional Value-at-Risk Model, means that it is within a given time period t. Under a certain level of confidence and normal market conditions, the potential loss of an asset portfolio is greater than the expected loss of Va R under a given condition. Its mathematical expression is:

$$CVaR = E\left[f(x,y)\middle|f(x,y) > VaR_a\right] = VaR_a + E\left[f(x,y) - VaR_a\middle|f(x,y) > VaR_a\right] \quad (8)$$

In the formula, $E[f(x,y)]$ represents the expected loss function of the asset portfolio, x represents the weight of the asset portfolio, y represents the market factor that causes the asset value loss, and a represents the confidence level.

RESULTS AND DISCUSSION

The research object of this article is the competitive market risk of nanocomposite companies, so this article selects the empirical analysis of the nanocomposite market index. The network experiment environment studied in this paper is shown in **figure 3**. A simulation experiment platform is created in this experiment environment, and then simulation experiments are performed to verify the effectiveness of the method in this paper. In this environment, the internal network contains five hosts, and a firewall is established between it and the external network. There is a hacker in the external network trying to attack the internal network host.

Under the above network environment settings, the corresponding experimental results are obtained by inputting the corresponding calculation formula into the computer. The specific process is as follows.

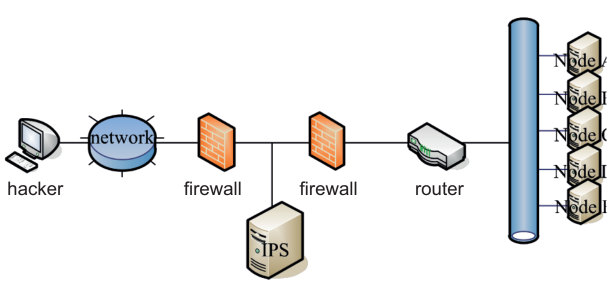

Fig. 3. Schematic diagram of experimental environment.

According to the market Va R theory, the return rate of nanocomposite companies is the most important factor to measure market risk. The specific calculation formula of the rate of return is as follows:

$$R_t = IN\left(P_t \middle| P_{t-1}\right) \quad (9)$$

In the formula, R_t represents the geometric rate of return on day t, and P_t represents the market price on day t.

According to the calculation results of the above formula, the VaR value and the actual logarithmic rate of return in the competitive market of material enterprises are obtained as shown in **figure 4**.

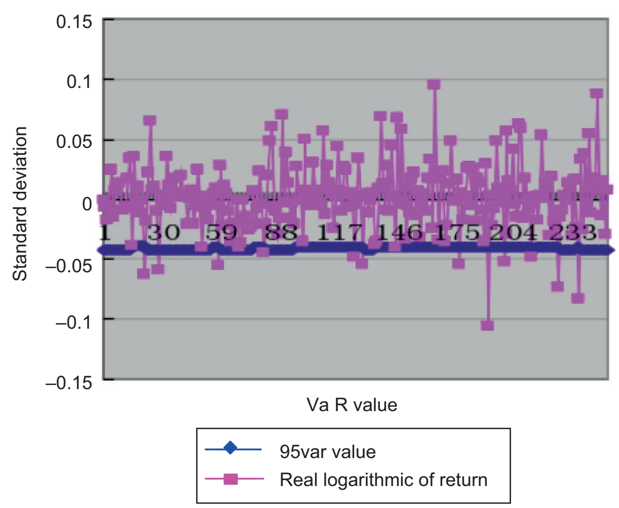

Fig. 4. Comparison of Va R value and actual logarithmic rate of return in the competitive market of materials companies

In **figure 4**, the violently fluctuating curve is the actual logarithmic return rate of the nanocomposite market, and the relatively stable curve is its Va R value. We can see that the actual logarithmic rate of return fluctuates around the value of 0, most of which are higher than the value of Va R. Only in extreme cases will it break the Va R curve. If the actual logarithmic rate of return on a certain day is above the Va R value, it means that the competitive market risk on that day is relatively small. Otherwise, it means that the market risk on that day is relatively high. Therefore, the historical simulation model successfully predicted the market risk, but in fact the composite material itself is also amplifying the market risk, and relevant companies should still pay more attention.

The risk assessment value refers to the possible degree of influence or loss brought by the quantitative evaluation of market competition factors:

$$R_L = \sum_{i=1}^{n} M_i \overline{R}_i \tag{10}$$

In the above formula, $\overline{R}_i$ represents the weighted average of the operation and maintenance management risk of each market competition factor, and M_i represents the weight of the influence of competition factors on market competition.

Figure 5 is a comparison chart of risk assessment readiness.

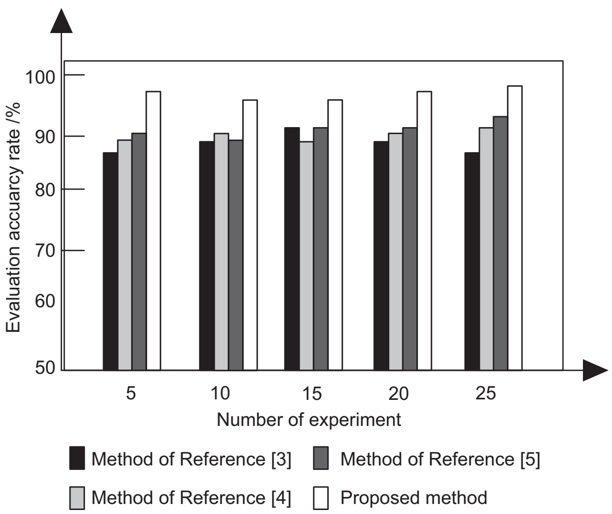

Fig. 5. Comparison of risk assessment accuracy.

As can be seen from **figure 5**, the risk assessment accuracy of the method in this paper is relatively high, close to 100%. The main reason is that the method in this paper mainly uses the AHP method, according to the idea of decomposing and then integrating, through the pairwise comparison of risk indicators. Rigorous calculation and sorting of the risk weights of risk factors at all levels in the risk assessment index system to reduce the influence of external interference factors was performed, thereby improving the accuracy of risk assessment.

It is known that TSV indicators can directly reflect the transmission sensitivity of risk prediction data. Under normal circumstances, the lower the TSV indicator value, the stronger the transmission sensitivity of risk prediction data, and vice versa. Sensitivity analysis mainly analyzes the effect of risk factors on accidents by changing the distribution probability of each risk factor (basic event) and observing its influence on the probability of risk events. The calculation method is as follows:

$$SPM(X_i) = \frac{1}{q_i}\sum_{1}^{q_i}\left|\frac{P(T=t|X_i=x_i)-P(T=t)}{P(T=t)}\right| \tag{11}$$

In the above formula, t represents the level of the risk event T, and x_i represents the level of the risk factor X_i.

Figure 6 reflects the specific changes in the TSV indicators of the experimental group and the control group a and control group b during the established detection time.

The analysis of **figure 6** shows that the TSV index of the experimental group reaches the maximum value of 30% when it is between 15 and 20 minutes. The TSV index of the control group b shows a relatively obvious fluctuating trend during the entire detection process, and the global maximum value is close to 75%. It far exceeds the value of the experimental group. The TSV index of the control group c reaches the maximum value of 60% when it is between 5 and 10 minutes, which is also higher than the numerical level of the experimental group. In summary, compared with the dynamic game supervision model and the Map model, after applying the risk assessment model of the method in this paper, the TSV indicator begins to decrease significantly, that is, the transmission sensitivity of risk data is effectively improved.

Since the 1990s, due to the potential application prospects of high-tech fields, the research of nanofiber technology has focused on the basic forming

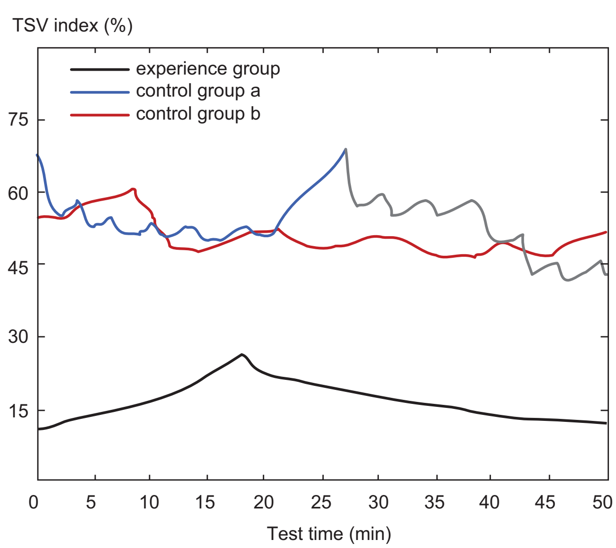

Fig. 6. Comparison of sensitivity of risk data transmission.

process, fiber structure and processing equipment. In recent years, the application research and development of nanofibers has accelerated significantly, especially the development and changes of functionalized nanofibers. The development trend of nanofibers and nanotechnology is the same, and more and more commodities will enter people's real lives. But at the same time, it should be clearly realized that compared with traditional spinning technology, the manufacturing process of nanofibers still has defects such as low production efficiency and high processing cost. In addition, the solvents used in electrospinning can cause environmentally friendly issues and also increase the cost of recycling equipment. It can be said that nanofiber technology and application research need to face many challenges, including the technical economy of nanofibers, solvent recovery and environmental friendliness, research on nanofibers and human health and the environment, and packaging and sales of nanofiber products (Liu et al. 2019, He et al. 2021). In any case, the trade-off between the high performance of nanofibers and the cost of manufacturing will be one of the topics that people are most concerned about. For example, some scholars have clarified and acquired the knowledge of drug adsorption on carbon-based nanomaterials (CNMs), which is very important for the chemical engineering application of CNMs, risk assessment and pollution control of CNMs and drugs. The adsorption mechanism and thermodynamic calculation of 18 most common drugs were used to evaluate the four different CNMs (primitive/functional fossil graphene and carbon nanotube) in two different solvents to provide (water and n-octanol) (Ivankovi et al. 2021).

CONCLUSION

In this paper, the analytic hierarchy process is used to establish the market competition risk assessment system of nanofiber composites, and after determining the corresponding weight, the fuzzy clustering algorithm is used to identify the bad data in the market competition data, and the CVa R conditional risk value model is constructed to realize the risk assessment. The experimental results show that the actual logarithmic return fluctuates around 0, most of which are higher than Va R. Only in extreme cases will it break the Va R curve, the accuracy of risk assessment is close to 100%, and the TSV index begins to decline significantly. In other words, it effectively improves the transmission sensitivity of risk data.

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