Characteristics Analysis for Volatile Organic Compounds Emission of Wood Furniture

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Abstract: Interior decoration with man-made board is a kind of common porous material, which is solid skeleton and the fluid inside the complex mixture. The establishment of the interior decoration of multiphase multidimensional model of mass transfer of volatile organic compounds released by artificial board, and based on the geometrical characteristic of wood-based panel thickness is thin, the artificial board TVOC release multiphase multidimensional model of mass transfer is simplified to a one-dimensional heterogeneous mass transfer model, and the solution and numerical simulation of one dimensional model. This paper use man-made board to release characteristics of volatile organic pollutants on decoration. By theoretical analysis and experimental methods of artificial board TVOC release are discussed. The finite element method is introduced into the furniture structural mechanics research, the study of the computer finite element simulation analysis was applied for determination of furniture structure design and mechanical properties of the theoretical foundation, system construction and concrete methods.

Keywords: Multiphase mass transfer model, release characteristics, wood-based panel, volatile organic compounds.

1. INTRODUCTION

With the social awareness of environmental protection, volatile organic compounds in indoor air quality problems caused by, people pay more and more attention [1-3]. The use of a large number of man-made board room decoration, make it become the main source of TVOC. In order to improve indoor air quality, management of indoor volatile organic compounds, the release mechanism and the influence factors of wood-based panels are fully aware of the TVOC. This paper studies the interior decoration of the common market for artificial board TVOC release mechanism and influencing factors [4]. The establishment of artificial board TVOC release multiphase mass transfer model; analysis of environmental factors such as temperature, relative humidity effect on board TVOC release and characteristics; finally, the release of TVOC prediction model and method [5].

Indoor air pollution has become a serious problem and promote the development of the VOC of the control measures, there are three main ways: source control, ventilation and air purification [6, 7]. The source of governance the most potential are the most effective, not only can avoid mechanical ventilation energy consumption but also can avoid the problem of air purification by-products when possible, is a fundamental method put things right once and for all. The governments and trade associations have been established which fits the situation of our country health standard, the provisions of the main VOC in the indoor environment and building materials in the limit of concentration VOC emission limit [8-12].

To understand the factors of the release mechanism of interior decoration materials, has important significance for the study of indoor air quality and pollution problems. Diffusion and transformation of pollutants in the environment is an important subject in Environmental Science and engineering of scientific research. This paper intends to analyze the mechanism of diffusion of volatile organic pollutants in porous building materials and indoor air in from the point of view of dynamics in porous media, and the porous materials as the research object to explore the particleboard; influence of environmental conditions on the release of volatile organic pollutants in particleboard, theory basis and scientific method for the effective control of man-made board caused by indoor VOC pollution [13-16].

Finite element method to solve the structure stress analysis problems very applicable, is widely used in many complex structure strength, stiffness, stability analysis and calculation has become the most effective method in structure analysis field. With the development of computer technology, finite element method for computer simulation analysis and went on to become the product design performance analysis and simulation is a very effective method. This thesis is based on the finite element method as the basic theory, computer simulation technology research of solid wood frame type furniture structural mechanics, in-depth and systematic study.

2. RELATED METHOD AND THEORY

2.1. Research on Dynamic TVOC Release

Theoretical study is established based on mass transfer theory, is widely known as the mechanism model and physical model, some parameters in the model, each parameter has its fixed physical meaning in them. The
establishment of mechanism model has very important significance for the release mechanism of TVOC research in building materials [17, 18].

The VB model was established by Guo and VBX model, TVOC model is to describe the diffusion of the classic, the model ignores the internal diffusion resistance, the concentration of TVOC assumed material film with uniform, get [19]

\[ R = h_m \left( \frac{\rho_d M}{M_o} - C_m \right) \tag{1} \]

The R release rate; HM convection mass transfer coefficient; M is TVOC the amount of material remaining in the C; TVOC concentration in indoor air; PV is the initial steam pressure. So the model can be used only with the control action on evaporation process [20].

Little et al. established analytical model of TVOC dry material distribution, Xu and Zhang, improved Little model, the control equation of material, material air interface and the air side, diffusion model are as follows:

\[ \frac{\partial C_m}{\partial t} = D \frac{\partial^2 C_m}{\partial x^2} \tag{2} \]

\[ -D \frac{\partial C_m}{\partial x} = h_m (C_{av} - C), \quad x = l, 0 \leq t \leq T \tag{3} \]

\[ V_c \frac{dC(t)}{dt} = A_m h_m (C_{av} - C) \tag{4} \]

This material is the diffusion coefficient D, CM as the material of internal TVOC concentration. They carried out numerical simulation of dry material, and study the impact of initial concentration, the internal diffusion coefficient, separation factor and material life are effect on release of material TVOC [21].

2.2. Several Commonly Used Physical Quantities in Porous Media

The porous medium is assumed to be a connected pipe network, in this model, each tube is fixed space flow tube, the flow with the same geometry. The concept of curvature is the piezometric head Carman in 1937 at a rate of a bent in a capillary tube average and difference at both ends and first introduced in the. Suppose there is a length of La pipe, connected on both ends of the line length is L, the direction of the line called s, he defined the curvature in the direction of L/La. For the porous media is bending rate is two rank tensor, denoted as [22]:

\[ T = \begin{pmatrix} T_{11} & T_{12} & T_{13} \\ T_{21} & T_{22} & T_{23} \\ T_{31} & T_{32} & T_{33} \end{pmatrix} \tag{5} \]

For the isotropic medium, the curvature tensor can be simplified to a simple scalar, the Baer in the dynamics of fluids in porous media has been proved. Experience in numerical curved rate proposed by Carman was 0.71, the average curvature values given in the literature changes in the range of 0.56 to 0.8 [23].

Because of the porous material is a multiphase mixture, its density is composed of solid skeleton and multicomponent gas CO decision, if the porosity is ε, the solid skeleton and the density of the gas is respectively ρd, ρ, the average density of ρ:

\[ \bar{\rho} = \rho_d (1 - \varepsilon) + \rho \varepsilon \tag{6} \]

3. THE ESTABLISHMENT OF MULTIPHASE MASS TRANSFER MODEL

TVOC release in artificial board can be divided into three processes, namely the internal sheet, plate interface and the release [24, 25]. As shown in Fig. (1).

![Fig. (1). TVOC release in artificial board.](image)

The area of the four sides of the artificial plate relative to the plane area is very small, little effect; in addition, in the experimental study, often with lead edge treatment, edge. Four sides of a hypothesis of non volatile organic pollutants, man-made board released as a double-sided board release.

The building is placed between two identical modules, as shown in Fig. (2), a class with a constant concentration of VOC, while the other class with clean air, the concentration at the outlet of the record two cabin is hourly. When the mass transfer process reaches a steady state, according to the diffusion law, the diffusion coefficient of Dm can be calculated by the formula:

\[ D = \frac{m \Delta x}{A \Delta c} = \frac{QL}{A C_1 - C_2} \tag{7} \]

The traditional method of furniture design is not a true analysis of furniture, can only use a simplified model to replace it for analysis, because it is difficult to know the full force of a real furniture in the process of using various components. They are usually simplified into an imaginary furniture model to analyze, and on the assumption of a simplified model of the furniture parts no weight, node is completely free to rotate in the complex situation, super static structure, all components and nodes as a whole structure to consider their deformation, as long as the ideal structure properties and real structure are similar, except for
special precise design, it will be the results of this analysis are applied to practical furniture design.

Fig. (2). The building placed between two identical modules.

Furniture structure computer aided optimization design, system integration, software is by the material's properties, furniture structure model, finite element software analysis module is composed of a of furniture structure and mechanical strength of aided design and determination of the evaluation of the collection system. Software system need to build through the material test and solid modeling, material parameter database and furniture entity models library is established, then the property parameter of material and furniture solid model corresponding to the ANSYS finite element analysis software simulation analysis and calculation and the results were analyzed, the output results, and according to the need to optimize the design.

4. EXPERIMENTAL RESULTS

4.1. Test Apparatus and Instruments

The sealed environmental chamber material was shown in Fig. (3). In order to reduce the environmental chamber wall adsorption / desorption effect of VOC gas, the entire cabin made of stainless steel, and the environmental chamber wall polishing treatment, which can meet the ASTM standard. The sealed environmental chamber diameter 300mm, high 430mm, the cavity volume is 30L; environmental chamber at the top of a DC fan, to produce a similar indoor mobile environment, and make the cabin VOC mixing.

From an analysis of the above shelf of deformation and stress, deformation is smaller than the amount of deformation of the provisions of the standard, each component stress were in the stress within the limits of, can satisfy the use requirement, design reasonable, but supporting shelf of the bookcase pieces joint stress concentration is more serious, you can through the support piece connection position optimization design can improve the stress state, make the design more reasonable, prolong the service life.

Efficient use of wood resources to the important role in alleviating the contradiction between timber supply and demand, thus promoting the rise and development of furniture, furniture to become mainstream products on the market. With the development of society and the progress of science and technology, people demand for high quality furniture products are increasingly strong, structural strength of furniture products design is increasingly furniture production and research departments, the structural strength of furniture design also requires the continuous development and improvement. This paper uses the finite element theory, ANSYS analysis software and optimization design technology as the foundation, through the theory analysis, computer simulation, experimental research methods, structure of plate furniture, connection mode and the connection position by theoretical analysis, experimental research and optimal design.

4.2. The Analysis of Results

This paper mainly to the formaldehyde density board as the target pollutants were studied, so as to formaldehyde gas detection to detect environmental compartments closed. Formaldehyde gas is injected into the empty cabin without building materials in the seal chamber, recorded by formaldehyde concentration decay curve. If not considering the cabin wall surface adsorption, the concentration of formaldehyde in the cabin environment described by the following equation:

\[ V \frac{dC_a(t)}{dt} = Q[C_i - C_a(t)] \]

The environmental chamber, the air is generally slow and uniform, and the concentration of formaldehyde on the outside leakage does not trace the impact, so it can be concluded that Q and Cm are constants, which can get the solution of the above equation is:

\[ \ln[C_a(t) - C_{in}] = -\frac{Q}{V} \cdot t + \ln(C_i - C_{in}) \]

In the measured attenuation curve of formaldehyde concentration in the cabin environment, according to the type
of slope (2–13) were in the form of linear fitting. Fig. (4) for tightness detection results of test temperature of 25 °C, can see the hourly air leakage is only 0.35% of the environmental chamber volume, the air leakage compared with the effect of building materials distribution process of VOC concentration in the cabin environment can be ignored.

Fig. (4). Tightness detection results of test temperature of 25 °C.

Fig. (5) shows the variation curve with the concentration of formaldehyde by monitoring the cabin environment.

Solid model based, each piece of model establishment is in the detailed structure of original research object and scale analysis based on the development. Main frame structure, furniture is the main body of the scale and proportion. The shapes and the sizes of main components are maximally and true consistent. In addition component bonding form can be measured for a specific connection form and scale in accordance with the actual measured value modeling, cannot be measured according to the similar bonding and birch joint technical requirements modeling. For too complex and in the structure of modern furniture very little uses the type of joint, according to the modern form of processing be appropriately simplified.

Traditional furniture component form and joint changes a lot, and there are many molding, carving and other decorative elements. In the model to establish if completely faithful to the real body need to spend a lot of modeling time. And too much camber line elements in front of the ANSYS software processing of grid division will bring larger problems, will also affect software operation speed and accuracy. For furniture structural mechanics analysis should be in typical structure and component based, contributing little to the structural strength and even unrelated elements can be simplified and even to, it would not be possible to make the research more universal and representative.

CONCLUSION

This paper focuses on the use of wood-based panel decoration volatile organic volatile matter release properties were studied. The theoretical analysis and experimental methods of man-made board TVOC release mechanism and release characteristics were discussed. According to the properties of porous artificial plate with interior decoration, the interior is the solid skeleton and the fluid in complex mixture, based on the continuum hypothesis and the law,
establish the interior decoration of multiphase multidimensional model of mass transfer of volatile organic pollutants released by the board; and based on the artificial plate thickness is thin, the TVOC concentration gradient parallel to the direction of thickness the direction of the volatile organic compounds in artificial board released multiphase multidimensional model of mass transfer is simplified to a one-dimensional heterogeneous mass transfer model, and the solution of the one-dimensional model and numerical simulation.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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