Development and design of virtual simulation system for rubber mixing process

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Abstract: Based on rubber processing research, this article utilizes computer technologies such as Unity3D and 3Dmax to construct a three-dimensional scene and process flow of the rubber mixing workshop. It designs and develops a virtual simulation system for the rubber mixing process. This system features perspective observation of the internal process, supports free movement for visitors, has strong interactive simulation capabilities, and professional page design. Taking the F270 type internal mixer as an example, the system demonstrates the structure and working principle of the main equipment and achieves interactive operation, fully reflecting the advantages and characteristics of combining rubber mixing technology with a virtual simulation platform.

Key words: rubber mixing process; virtual simulation; Unity3D; interactive simulation

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0 Introduction

The rubber product industry is one of the important basic industries in the national society. The development of the industry reflects the overall development level of the national economy and modern high-tech fields. Vigorously promoting informationization and automation technology and realizing the standardization and intelligence of rubber production are also trends in the industry's development. There are various types of rubber products, and their production processes are basically the same. Among them, rubber mixing is an extremely important process . Raw rubber undergoes multiple stages of plasticizing through various equipment such as open mills, internal mixers, upper and lower auxiliary systems, rubber sheet coolers, and rubber cutting machines . After batching, mixing, and sheet pressing, it obtains mixed rubber compound that meets performance requirements, preparing for subsequent molding processes.

Due to issues such as multiple mixing unit equipment, large footprint, complex operational processes, and difficulties in manual operation in the real-world rubber mixing process, a virtual simulation system is constructed using computer technologies such as Unity3D and 3DMAX to mimic real factory production scenarios. Key operational processes are simulated with real-time interaction, providing users with an immersive experience while allowing for free exploration and interaction . The system possesses unique advantages such as interactivity, learnability, ease of operation, and fun, making it suitable for training and teaching purposes. For personnel in the rubber products industry and related enterprises, it allows for a full integration of theory and practice, enabling them to master practical skills and achieve self-learning outcomes.

1 Design process of virtual simulation system for rubber mixing process

This system takes the rubber mixing process as the research object, uses the F270 type internal mixer as the physical model, and takes tire manufacturing enterprises as the prototype to carry out high-fidelity design of scripts,

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experiments, and scenes. 3DMax is used to construct the three-dimensional scene and process flow of the rubber mixing workshop, and all the built models are placed in the Unity3D platform for association. C# coding is used to implement the interaction process between various instruments and equipment. The design process of the virtual simulation system for rubber mixing process is shown in Figure 1.

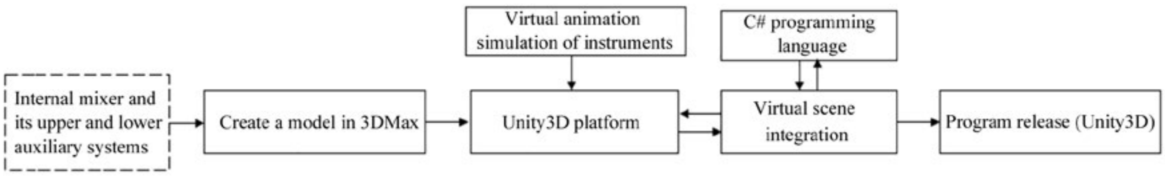

Figure 1 Design process of virtual simulation of rubber mixing process

2 Composition design of virtual simulation system for rubber mixing process

Firstly, modeling is carried out for the rubber mixing unit, with the main modeling equipment including the carbon black storage and powder weighing system, oil conveying and weighing system, rubber cutting machine, belt conveyor, internal mixer, open mill, rubber sheet cooler, etc. . For the rotating and movable structural parts of the equipment such as couplings, shafts, rotors, etc., coordinate axes are set up for separate modeling to facilitate the implementation of the instrument's motion process and assembly process. Due to the numerous equipment, the carbon black storage and powder weighing system is taken as an example for design description, and other parts are designed and implemented according to similar steps.

There are various types of carbon black, which serves as a reinforcing agent for rubber and is an indispensable raw material in the rubber mixing process. Due to the need to add multiple types of carbon black during the batching process, multiple sets of carbon black storage tanks have been designed. Based on these characteristics, modeling design was carried out with reference to the physical model of the enterprise. Firstly, diffuse reflection was performed using software to add materials, followed by rendering processing to obtain detailed scene textures. Textures were attached to different materials, pipelines, and equipment, which were then imported into the Unity3D platform separately. The relative positions of each part were arranged on the platform. Virtual simulation modeling was conducted for the pipeline connections, circuit distribution, and scene lighting of the carbon black tanks in the scene, enabling them to have the function of decentralized feeding. Finally, a highly simulated three-dimensional model was achieved, reflecting the simulation nature of the carbon black storage model. The comparison between the modeling of the carbon black storage tank and the actual scene is shown in figure 2.

Figure 2 Comparison between the modeled black storage tank and the actual scene

The feeding process of carbon black and the weighing process of powder are implemented through a particle system on the Unity3D platform. The particles are dynamic, and their size and speed can change with the change of cycle or speed. Firstly, create a scanning effect by adding color, scanning width, and other attribute values to the model of the part that needs to be transparent; then establish a formula to define the direction, shape, and size of the particle emitter, set the initial state and gravitational acceleration; change the object material to transparent material to avoid being too rigid, and overlay brightness, then start to implement the transparent function. Through multiple V-Ray rendering engines, the transparent effect and animation display effect are achieved. Finally, the simulation of transparency is demonstrated for observation, and the process of feeding material through the internal spiral structure can be clearly seen. The feeding effect diagram of the carbon black feeder is shown in Figure 3.

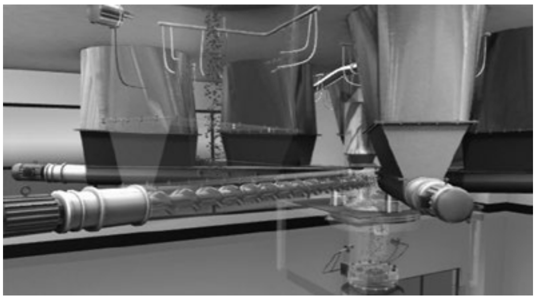

Figure 3 Feed effect diagram of carbon black feeder

The above demonstrates the design of the process for storing carbon black and weighing powder materials. In addition, the oil injection process, rubber cutting and transportation process, rotor operation mode inside the mixer, and rubber sheet cooling process all utilize visual virtual simulation design. This addresses challenges such as the lack of insight into internal operating conditions due to the enclosed nature of the equipment, which only allows for partial observation, and the absence of a deep understanding of the processing principles.

3 Development of the effect of the virtual simulation system for rubber mixing process

3.1 Free observation effect

Based on practical operational needs, the virtual simulation system is designed to enable free observation and exploration of large equipment such as internal mixers and open mills through camera manipulation, facilitating a comprehensive understanding. The use of collision avoidance design between object models on the Unity3D platform enables an immersive free-view experience. The panoramic view of the internal mixer unit is shown in Figure 4.

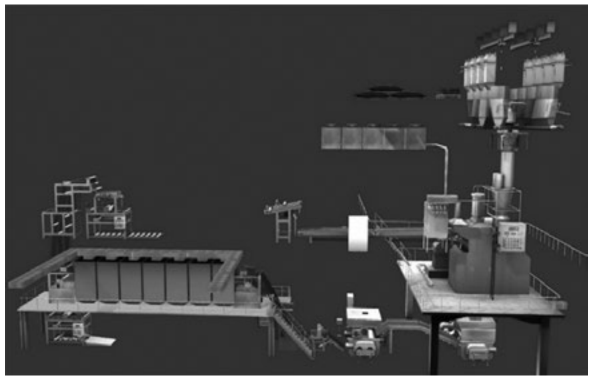

Figure 4 Panoramic view of the internal mixer unit

3.2 Scene interaction effect

Scene interaction primarily involves roaming operations from a first-person perspective . The main camera is selected as the primary viewpoint, and the character's free movement is controlled through the use of W, A, S, and D. The main camera follows the character, and during movement, the device performs collision detection, specifically detecting obstacles such as factory columns and equipment, and finally presenting the data. The overall scene is primarily modeled around a rubber compound workshop. The workshop consists of four floors, each with a different design. From top to bottom, the fourth floor is for storing carbon black raw materials, the third floor for storing oil and weighing carbon black, the second floor for internal mixing, and the first floor for sheet pressing. Interaction is controlled through buttons. Taking the interaction function of the internal mixing process on the second floor as an example, first, according to the rubber compound formula sheet, add raw materials in sequence. Add the required weight of raw materials for raw rubber, protective agent, vulcanizing agent, softening plasticizer, and other additives in the corresponding numerical boxes. After entering the correct values, click the corresponding plus button to proceed to the next step. If the input is incorrect, the operation cannot continue. After all raw materials are added, the interaction starts the belt conveyor to achieve a series of actions such as relative movement, thus achieving the effect of virtual interaction in the scene. The interaction effect of the internal mixing workshop is shown in Figure 5.

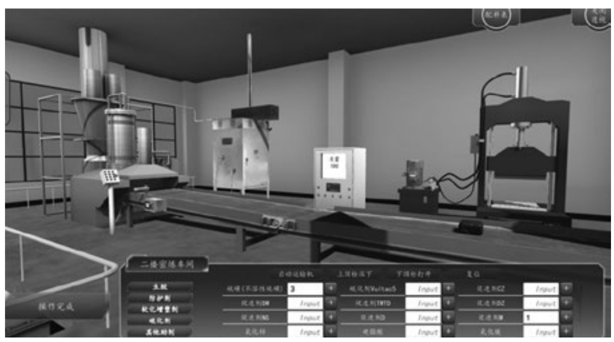

Figure 5 Interactive effect in the mixing workshop

3.3 Scanned perspective effect

The system employs scanning perspective to better understand and observe the internal structure, movement, and assembly of large instruments. This function is exemplified by the rotor movement of the internal mixer. Within the mixing system composed of the rotor, mixing chamber wall, upper ram, and lower ram, the material is subjected to constantly changing and repeated shear, tear, and agitation, thus achieving the purpose of mixing. By demonstrating and observing through simulated perspective, the internal rotor structure can be clearly seen, and the real feeling brought by the shear deformation of the rubber compound can be experienced. The comparison diagram of the perspective effect of the internal mixer rotor is shown in Figure 6.

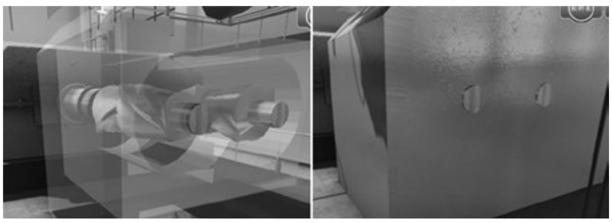

Figure 6 Comparison of perspective views of mixer rotors

4 Conclusion

Based on the above design, a virtual simulation system for rubber mixing process has been developed, featuring perspective observation of internal process, free movement for visiting, strong interactive simulation, and professional page design. By combining virtual reality technology, the overall system design has been completed, and multiple system operation optimizations have been carried out to achieve smooth system operation. This meets the interactive requirements of virtual simulation for rubber mixing process, reduces the cost of factory internship training operations, ensures the safety of workers' practical exercises, and enables learning anytime and anywhere through the platform, achieving full utilization of resources.