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OPTIMIZATION OF MANUAL HANDLING OPERATION DURING FURNITURE MANUFACTURING

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Abstract:
Manual handling has always been a common task in the Chinese furniture manufacturing industry, which is easy to cause fatigue. In order to improve the man-machine cooperation in the machining of furniture, and to alleviate the fatigue of workers, the optimization of manual handling operations is discussed in this paper from three aspects: planning of working time, improvement of operating posture and optimization of workbench size. In addition, this paper shares the design of a bending-free boards rack, which is based on the purpose of reducing the worker's back muscle load during operating. In this paper, the optimization of manual handling could be used for reference in the manufacturing industries where manual operations are intensive.

Key words: *manual handling; man-machine cooperation; work fatigue; bending-free; operation optimization.*

INTRODUCTION

In recent years, China's furniture manufacturing industry is undergoing a transition from traditional human-intensive type to information-based manufacturing type. With the application of information tools such as CAD and CAM in the mass production of furniture products, the dependence on workers has been reduced (Wang 2017). Although the number of workers in a furniture workshop has declined, the workload of individual workers might increase in many cases.

Manual material handling has been commonly demanded among furniture manufacturing processes, such as loading, drilling, milling, assembly, etc. During repeated handling, muscles on the body parts such as the arm, neck and shoulders, and lower back are prone to fatigue after frequent contraction activities. Excessive workload, improper work posture, and long-term repetitive muscle fatigue lead to an increased incidence of work-related muscular-skeletal disorders (WMSD) (Rashedi & Nussbaum 2016). Related research in China during recent years shows that, no less than 39% of manual workers among various industries, including furniture manufacturing, have suffered from WMSDs, especially low back pain (LBP) and neck/shoulder pain (NSP) (Yue et al. 2014, Feng et al. 2016).

Based on the investigation and simulation of the load level and fatigue process of workers during manual handling in furniture manufacturing, an operation optimization scheme for repetitive manual handling was proposed to alleviate muscle fatigue and improve work efficiency. In addition, the design of the bending-free equipment was discussed in the present study.

ANALYSIS

On the one hand, the work fatigue is caused by excessive local load during handling. Excessive local load can be caused by long-term static contraction or excessive force of the muscle. That is, long-term single posture exertion and compulsive force operation are probably to cause muscle fatigue contraction, resulting in muscle soreness and strength decline (Dantas & de Lima 2015).

On the other hand, work fatigue is caused by continuous repetitive operation. This type of operation exists in a large amount in the loading and assembly processes. Both G Sundelin's study on the shoulder muscle fatigue during continuous repeated grasping operation (Sundelin & Hagberg 1992), and T Bosch's study on the neck and shoulder muscle fatigue during long-term assembly work (Bosch, De Looze, & Van Dieen, 2007), have shown that though the muscle load is low in continuous high-frequency repeated operations, significant fatigue occurs during normal working hours. In addition, referring to W Dai' s study of forearm muscle fatigue in repetitive wrist movement (Dai *et al*. 2006), and F Zhang's study of upper limb muscle fatigue in repeated operation (Zhang *et al*. 2007), it is found that when the number of movements in the operation reaches a certain level, the primary factor that causes muscle fatigue in the upper limbs is the frequency of action, not the workload.

OPTIMIZATION, DESIGN AND DISCUSSION

Handling operation optimization

Referring to the typical operation of the furniture workshop involving loading and unloading, the operation optimization scheme is designed as follows.

- *Planning of working hours*

According to the occurrence and change of the fatigue of back muscles in the repetitive bending-handling task, it has been found that the single operation should not last too long. Therefore, increasing short-term intermittent rest is capable of effectively controlling the occurrence of lumbar muscle fatigue (Shin & Kim 2007).

For manual handling task with a handling weight of 5 kg, a frequency of 15 times/min, and a lifting distance of 250 mm, waist fatigue generally appears at 7 to 10 minutes. Therefore, during the continuous loading/unloading task, single loading cycle need to be controlled within 10 minutes. For a fixed standing or sitting position feeding/sorting task, which rarely involves dynamic contraction of the lower back muscles, the fatigue of the arms and neck and shoulder muscles is relieved quickly. Therefore, the single cycle of this type of operation can be extended to 20 minutes or even longer.

- *Improvement of operating posture*

During bending-handling task, most workers are accustomed to bending down, and lifting up/laying down boards, directly. Zhao's study on the binding of sofa frames using human simulation shows that this bending-and-lifting movement is extremely harmful to the spine and the back muscles. Zhao's study on manual lifting operation using surface electromyography (sEMG) shows that lifting the load in a semi-squatting posture, with the back straight, is more reasonable (Fig. 1). This semi-squatting-and-lifting movement is able to protect the muscles on the back and waist. Meanwhile, the strength of shoulder and arm can be better exerted.

Fig. 1.
The bending-and-lifting movement.

In addition, it is also necessary to optimize the matching and cooperation of workers at the same work post. For example, choosing two workers with similar body types, as well as similar physical strength, to cooperate with each other can ensure that these two have similar rhythm and high cooperation efficiency (Zhang *et al*. 2015).

- *Workbench size optimization*

At present, a large number of machine tools in China's furniture workshops are imported from Europe. The dimension design of the equipment is mostly based on the European human body's percentile. Such as the height of the loading table and the numerical control screen, the width of the workbench, and so on. In order to make the production equipment more suitable for domestic workers, avoiding the difficulty of lifting due to the high loading table, the inconvenience caused by the high numerical control screen, the difficulty of placing the workpiece due to the excessive width of the table, the above dimensions should be appropriately adjusted according to the Chinese human body percentile.

Design of the bending-free boards rack

- *Principle of the bending-free boards rack*

During the furniture manufacturing process, materials such as boards are generally temporarily stacked on the ground, or on the pallet, when they are to be processed and already processed. This causes the workers to bend down and lift up/lay down during the loading and stacking process, increasing the burden on the back muscles. If the height of the material pile is maintained slightly lower than the elbow height of the worker, by which guarantees that there is no need to bend down, the above problem would be overcome.

Based on this idea, Yu et al. designed a bend-free boards rack that combines infrared positioning and hydraulic lifting (Yu *et al*. 2015). As shown in Fig. 2 and 3, this device implies infrared light-emitting tubes to emit infrared rays and receive infrared rays, and forms an electrical signal by amplifying and rectifying them. When the side of the panel blocks infrared light, the signal processor outputs an instruction to open the flow valve and the speed limit valve of the hydraulic system. Therefore, the elevator is lowered until the infrared light is turned back on. Under the control of the single-chip microcomputer, the pressure oil valve is closed, and the lifting mechanism is stopped and stopped. When the inner plate of the loading rack is fully loaded, the side door of the box can be opened to remove the board neatly. After resetting the infrared signal processor, the motor-driven lift is raised back to the starting position with the push of the piston rod.

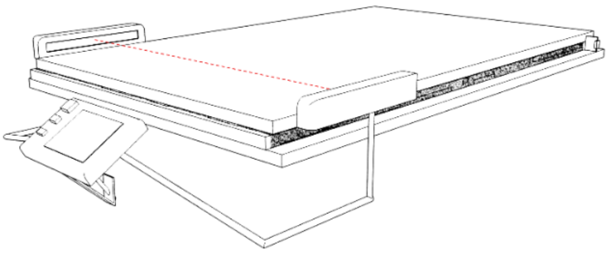

Fig. 2.
The infrared positioning device used upon the bend-free boards rack.

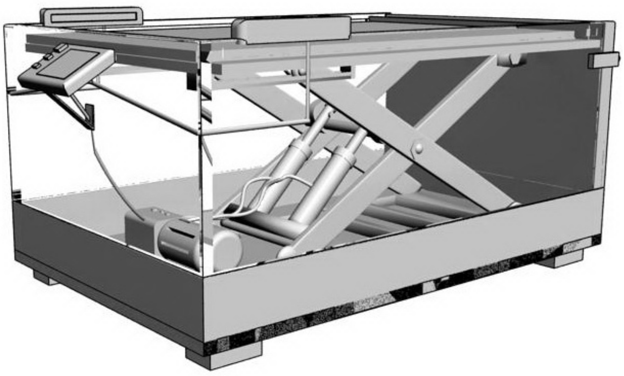

Fig. 3.
The hydraulic actuator inside the bend-fre boards rack.

- *Application of the boards rack*

The boards rack is designed to maintain the uppermost plane of stacked boards at a fixed height. The height is set as the lower end of the elbow of the operator (Considering the space limitation, the board size is not more than 1220×610mm^2, the number of boards of 18mm thickness is not more than 50 pieces). In this way, no matter how many boards have been left in the rack, the operator can always place and remove the board in the most convenient and labour-saving way.

As shown in Fig. 4, the application of the boards rack avoids excessive waist and back movements of the worker during manual handling, avoiding strain on the back muscles. In addition, this design can also effectively utilize the muscle strength of the shoulder and arm.

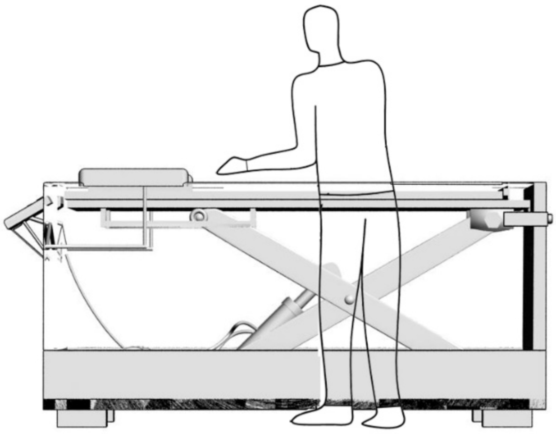

Fig. 4.
Application of the bend-free boards rack.

CONCLUSIONS

At present, the dependence of Chinese furniture manufacturing industry on human labour is still on a high level, and human-machine collaboration is not efficient enough. Therefore, the fatigue of workers' work is widespread. This paper focuses on repetitive handling operations, combined with field research and predecessor research, to optimize the human factors such as worker's movement habits, operating cycling, table measurements, etc. At the same time, it introduces the design of a bending-free waist loading rack.

Although the current level of automation and informatization of furniture manufacturing is constantly improving, the role of people within the manufacturing system has not diminished. In this case, it is necessary to improve human reliability and overcome the interference of work fatigue. This is of great significance for stabilizing the overall production efficiency.

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