The Design of a Double X-axis Gantry Bayonet Tufted Carpet Weaving Machine

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Abstract. In order to achieve high-quality and high-efficiency production of hand tufted carpets, a gun-punched tufted carpet weaving machine is designed in this paper. The carpet weaving machine is based on the development of Advantech industrial computer and Googoltech GTS-800-PG. The designed double X-axis gantry frame ensures continuous production speed of up to 1500 clusters per minute. The precise frame transmission mechanism realizes smooth curves, sharp Angle and small stitch angle movement under high density. This article mainly introduces composition of the control system and the design of overall mechanical structure of the carpet weaving machine, and looks forward to the development trend of the machine.

Keywords: Double X-axis; Bayonet; Tufting; Carpet weaving machine.

1. Introduction

At present, the carpet has become an important decorative material for normal family of city. The rapid development of informatization and automation, CAD / CAM technology and digital control technology are widely used in carpet weaving, which can greatly improve the efficiency of carpet production while reducing the rejection rate. The traditional carpet weaving technology with backward production methods has been difficult to meet the personalized needs of the current public, and many small and medium-sized carpet weaving enterprises in China still use traditional technology [1]. Overseas, such as British Cobble company, American CMC company [2], Tuftco company and Japan Yamaguchi Industry Co., Ltd. have mastered many patented technologies of tufting machine technology. Especially as the traditional tufting machine manufacturer British Cobble company masters the most advanced tufted carpet technology. The Booria company developed a CAD/CAM system based on computer-aided technology for the hand-made process of tufted carpets. This system can digitize the design pattern files and automatically analyze the patterns into control codes that can be run on Computer Numerical Control (CNC)machine tools. However, the CAD/CAM system must match with the specific standard CNC system platform and bayonet head, and the follow-up maintenance is relatively complicated and expensive, which leads to the obstruction of the product in the domestic market.

Due to backward domestic equipment and technology and carpet market demand, the domestic carpet tufting machine is mainly imported from American Tuftco and British Cobble company, CMC and Japan co., LTD. Related products are mainly terry tufting machines [3], ordinary cut pile tufting machines, and jacquard tufting machines with unidirectional or bidirectional mechanical cam movement, and the equipment is relatively backward. After several years of application, many manufacturers have improved the carpet tufting loom according to the actual application situation, which has promoted the development of the carpet industry to some extent. At present, the manufacturers of bayonet tufted
machines mainly include Yangxin Ruixin Group and Voltek. However, their devices can only handle one or several pattern format files, and many pattern formats are not compatible. In addition, due to the influence of the length of the robot arm, the size of the carpet is also limited.

Traditional hand-tufted carpets need to go through the initial pattern design, multiple stitching and printing photos, hand-drawn pattern outlines, plate making, color matching, dyeing, printing, hand-punching, and subsequent processing. However, the automatic bayonet tufted carpet weaving machine only needs CAD / CAM pattern design, professional pattern analysis software, automated operation and subsequent processing. In contrast, the automatic tufted carpet weaving machine optimizes the production process, shortens the construction period and improves the production efficiency.

2. Composition of Carpet Weaving Machine Control System

The overall control system of the tufted carpet weaving machine is shown in Figure 1. It is based on the solid high GTS-800-PG control card and R&D industrial personal computer, and the IPC is connected to the pattern processing system, synchronous distribution system and 8-axis motion control system respectively. The 8-axis motion control system is connected to the Panasonic A6 servo drive control system. The servo drive control system controls the double X-axis gantry mechanism and Y-axis door width, feed gun axis (Z axis), needle axis, rotating gun axis, thread feeding axis, and thread trimming axis respectively. Among them, the two AC high-power servo motors are driven by the double X-axis gantry structure so as to drive the whole machine to move left and right; One AC high power servo motor on Y axis drives the machine to move up and down; The needle shaft is driven by a servo motor; One servo drives gun shaft, then the gun body structure advances integrally; One servo motor is installed on the rotating gun shaft to drive the gun body to rotate; there are also two stepper motors, one of which drives the spool and the other is responsible for shearing. In addition, the thread break processing system of IPC, and a separate yarn break sensor is installed at the automatic winding device to automatically detect the yarn status and the yarn breakage automatically stops without false alarms.

Figure 1. Schematic diagram of the control system of the carpet weaving machine.

3. Design and Analysis of Overall Mechanical Mechanism of Carpet Weaving Machine

The mechanical mechanism mainly includes double X-axis gantry frame structure, Y-axis module, collapsible base fabric frame, gun head movement module, electric loom module, automatic wire feed,
yarn detection structure and control cabinet, as shown in Figure 2. Among them, the lower X-axis module of the double X-axis gantry structure module is fixed to the ground by anchor bolts, which plays a main role of fixing. The Y-axis module is installed on the upper and lower X-axis modules through double linear guides. The double X-axis gantry structure enhances rigidity, reduces transmission mechanism, and improves repeatable movement accuracy. The gun head mounting module is connected to the Y-axis through a guide rail and servo motor, and the gun head mounting module can move up and down in the Y-axis direction. The electric weaving gun module is connected to the gun head mounting module through the linear guide and servo motor. The electric weaving gun can be driven by the crankshaft to make the needle mechanism and the thread trimming mechanism sequentially extend and retract in the Z-axis direction by the servo motor. Support modules are installed on the both sides of the machine to strengthen the overall structural strength and reduce machine shaking.

![Overall mechanical structure diagram of carpet weaving machine.](image)

**Figure 2.** Overall mechanical structure diagram of carpet weaving machine.

3.1. Design of Double X-axis Gantry Transmission Mechanism

The double X-axis gantry transmission mechanism is mainly responsible for driving the Y-axis module to move along the X-axis and the overall support. When it moves along the X-axis direction, the overall weight of Y-axis module is relatively large[@1]. Therefore, a large impact force will be generated during acceleration and deceleration, so the selected transmission mechanism should be able to withstand a relatively large impact load[@2]. The design requires that the Y-axis module can move left and right in the X direction up to 6m (or even longer). Based on the above factors, gear rack motion mechanism with large bearing capacity, high transmission accuracy, continuous buttless length and fast transmission speed can be selected as the transmission device.

The servo control method is selected, the motor and gear are installed on the Y-axis module, and the rack is fixed on the upper and lower X-axis modules. When the servo drive gear rotates, the fixed rack by the reaction force makes the Y-axis module connected with the motor to move along the X-axis double guide. In order to make the movement accuracy higher and the movement more stable, the servo motor is used to drive on the double X axis.

3.2. Design of Y-axis Transmission Mechanism

The driving gun head mounting module relies on the Y-axis transmission mechanism to move up and down. Because there are only mechanisms such as tufted knitting guns, the overall weight is lighter and the impact force during acceleration and deceleration is also smaller. According to actual needs, when yarn breakage occurs during the tufting of the gun, the electric weaving gun needs to be moved down quickly so that workers can re-wire and other work. Based on the above factors, the Y-axis transmission mechanism also selects the gear rack motion mechanism.

3.3. Tufted Gun Head Module Design

The mechanical structure of the gun head mounting module is shown in Figure 3. The gun shaft motor
3, rotary gun shaft motor 4, gun head 6, and thread trimmer 9 are installed in the housing 5. The needle mechanism and the thread trimming mechanism are connected by a spline. The motor 3 drives the orderly entry and exit of the needle and the thread trimmer shaft through the crankshaft, and the motor 4 drives the rotation of the needle and trimmer shaft through a timing belt connected to the thread trimmer shaft (external spline). The Y-axis motor 1 is installed below the casing and connected to the Y-axis; the driving wheel 7 and the driven wheel 8 are installed behind the exterior of the casing; the gun head mounting module motor 2 is installed at the connection between the Z-axis and the mounting frame 10; the casing 5 and its The internal structure is mounted on the mounting frame 10. A servo motor is used for the gun shaft motor 3 to control the high-speed retracting and retracting of the gun head 6 in the Z-axis direction, and a servo motor is used for the gun shaft motor 4 to control the gun head 6 to perform high-speed rotation based on the Z-axis movement.

**Figure 3.** Mechanical structure of the gun head mounting module.

### 3.4. The Mechanical Structure of Wire Feeding Module

The mechanical structure of the wire-feeding module is shown in Figure 4. The wire-feeding device 11 is installed on the base frame 13; the hub 12 is fixed on the base frame 13. The thread bobbin is placed on the thread feeder 11. The thread feeder 11 is driven by a stepper motor to send the thread into the hub 12. After passing through the hub 12, multiple strands of yarn are gathered into a single strand of yarn and transported upward to the gun head installation module. The driven wheel 8 is driven by the driving wheel 7 in the gun head installation module, and the weaving thread is transported into the gun head to complete the thread feeding process. After the knitting is completed or a problem occurs during the knitting, the thread cutter 9 is driven by a stepping motor to cut the knitting thread to stop the knitting work.

**Figure 4.** The mechanical structure drawing of wire feeding module.
3.5. Product Technical Index

Table 1. Technical specification of prototype design.

| Technical Index           | Parameter                                                                 |
|---------------------------|---------------------------------------------------------------------------|
| Frame Size(mm)            | 6000×4000, 4000×3000 (Customized to customers)                            |
| Frame                     | Double X-axis gantry frame+ Y-axis frame                                   |
| Tufting Height            | Cut pile: 7—18mm, Loop-pile: 2—10mm                                       |
| Tufting Speed             | $V_{\text{Max}} = 1500$ cluster/min                                       |
| Production Efficiency     | Maximum capacity $5\text{m}^2/\text{h}$                                 |
|                           | (Influencing factors: Line spacing density, Yarn material and complexity) |
| Yarn Specifications       | Natural fiber—wool, cotton, hemp, bamboo, silk Etc.                       |
|                           | Synthetic fiber—nylon, oren, polypropylene, rayon Etc.                    |
| Working Voltage           | Single phase: 220 V AC 50-60hz                                           |
|                           | $P=1\text{ kW}$ (No air pressure required)                                |

4. Conclusion

During operation, because of the use of a single loom, it is not possible to weave yarn of multiple colors at the same time. Therefore, it is an important development trend to research on multi-machine collaborative carpet weaving machine in the future.

The control system of the carpet weaving machine designed in this article is based on an eight-axis control system developed by Advantech industrial computer and Googoltech GTS-800-PG. The power is 220 voltage single-phase power, no pneumatic components and no air pressure, which greatly improves the production quality of tufted carpet, and can be applied to a variety of yarns, the production speed can reach 5 square meters per hour. In addition, the compact machine, simple operation and low cost can widely replace production of tufted carpet by small and medium-sized enterprises or handicraftsmen.

References

[1] Huansheng Liu. The development of tufted carpet technology [J] Beijing Textile, 2002,23(3):7-11.
[2] Liping Liang. CMC: The most advanced manufacturer of tufting equipment in the world [J]. China Textile, 2017(06):105.
[3] Owen P. Danley pioneers novel applications for tufting technology[J]. Techncal Textiles International, 2005,(Jan/Feb).
[4] Ning Dong, Jun Du, Jiaying Wu, Hailong Chen. "Precise Positioning of the Tray Grabbing System Based on Machine Vision", Journal of Physics: Conference Series, 2018.
[5] Shuang Huang, Xinfu Chi, Yang Xu, Yize Sun. Dynamic characteristics of coupling shaft system in tufting machine based on the Riccati whole transfer matrix method[J]. SAGE Publications, 2017, 231(2).