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Structural Optimization of Polyurethane Sponge Cutting Machine Based on Modular Design

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Abstract: Polyurethane sponge has excellent properties and is widely used in home decoration, automotive, construction, packaging and other fields. With the improvement of people's living standards and their demand for a more comfortable environment, the demand for polyurethane sea surface has been increasing year by year in recent years. The increasing demand for polyurethane sponge has led to a surge in demand for polyurethane sponge cutting machines, and the competition for polyurethane sponge cutting machines in the market is becoming increasingly fierce. In addition to the functional requirements of the product, the appearance structure of the polyurethane cutting machine is also a hot topic of concern. Currently, the polyurethane sponge cutting machine has a simple structure and unreasonable design, which makes the cutting machine vulnerable to damage. And unreasonable structural design can affect users' work efficiency, increase production costs, and in severe cases, cause safety hazards. Therefore, this article analyzes the existing problems in the structure of gantry style polyurethane sponge cutting machines on the market, modularizes the polyurethane cutting machine, optimizes the structure of the cutting machine according to ergonomics, and designs an aesthetically pleasing design that can improve the efficiency and safety performance of the polyurethane sponge cutting machine.

Keywords: Structural optimization; Modular design; Ergonomics.

1. Introduction

Polyurethane sponge is a type of sponge made of polyurethane material, which has good elasticity, flexibility, and sound absorption properties. It is widely used in fields such as furniture, automobiles, construction, and packaging. In the furniture industry, polyurethane sponge is widely used as a filling material for sofas, mattresses, and other products, which can improve the comfort and durability of the products. In the automotive industry, polyurethane sponge is used as a soundproofing and shock-absorbing material, which can improve the comfort and safety of cars. With the continuous improvement of people's awareness of quality of life and environmental protection, the market demand for polyurethane sponge will continue to grow. Polyurethane sponge cutting machine is an important equipment for producing sponge products. With the intensification of market competition, the appearance structure of polyurethane sponge has gradually become one of the important factors for consumers to choose products. At present, the appearance structure of domestic polyurethane sponge cutting machines is simple, and the structure does not fully consider humanized design. The outer layer of the coating is prone to peeling off, resulting in insufficient competitiveness of domestic polyurethane sponge cutting machines in the market. Optimizing the appearance structure of polyurethane sponge cutting machine requires starting from multiple aspects, including body material, appearance coating, structural design, etc. In terms of body material, high-quality steel and aluminum materials should be selected to ensure the hardness and stability of the body. In terms of appearance coating, high adhesion and weather resistant coatings should be used to ensure the aesthetics and durability of the body. In terms of structural design, attention should be paid to detail processing, such as reducing gaps and burrs on the body, and improving the overall aesthetics. By optimizing the appearance structure of the polyurethane sponge cutting machine, the quality and market competitiveness of the product can be improved, while also helping to enhance the image and brand value of the enterprise.

Based on this, this article takes the gantry style circular blade polyurethane sponge cutting machine as the research object. In response to the problems of simple structure and lack of ergonomics in current sponge cutting machines, the overall height of the cutting machine is optimized, and the optimal height suitable for user operation is designed based on ergonomics. The polyurethane sponge cutting machine is modularized, and the beam and column modules of the cutting machine are structurally optimized. Finally, a sponge cutting machine with high safety, aesthetic appearance, and comfortable and convenient use is designed.

2. Currently, There Are Problems with The Appearance and Structure of Polyurethane Sponge Cutting Machines

From the perspective of appearance structure, the current domestic polyurethane sponge cutting machines lack exquisite appearance and only focus on the functional application of the cutting machine. Most of them are based on the product attributes of various functional parts of the cutting machine, and their design in appearance structure is too simple, lacking humanized design. In terms of the structural division of the circular blade polyurethane sponge cutting machine, the main body of the appearance consists of a crossbeam, a column structure, and a tool holder structure. In most existing sponge cutting machine products, the color of the outer paint is generally blue or a combination of green and orange. Due to maintenance issues, the outer paint film of the cutting machine is prone to peeling off, and some metal parts are exposed on the outside, which can easily oxidize and

cause rust stains. Therefore, more research needs to be conducted on key modules in each section to improve product structure, produce more high-quality products for users to choose from, and enhance user experience.

At present, polyurethane sponge cutting machine products basically do not have a shell structure, resulting in various parts of the machine being exposed and accumulating dust layers, increasing the difficulty of machine maintenance and reducing the service life of the machine. In addition, when processing in a relatively humid environment, the mechanical components of the cutting machine are prone to oxidation, which increases the frequency of replacement of key components, increases the cost of use, and is extremely prone to safety accidents.

In terms of the convenience of operation for users of polyurethane cutting machine products, due to the current semi-automatic design of polyurethane sponge cutting machines, the operation of sponge cutting machines cannot be separated from the operators. Therefore, the convenience and comfort of workers during operation are important considerations for designers of cutting machine products. The user's experience of operating a product can directly or indirectly affect the external image of the product and the user's work efficiency. At present, some products of polyurethane sponge cutting machines have messy operation buttons and unreasonable height settings, which increases the difficulty and fatigue of the operators' work. Therefore, structural improvements are made for the convenience of user operation.

Overall, there are still many problems in the structural design of existing polyurethane sponge cutting machine products, which require in-depth research on the structural design, humanized design, operational convenience, and structural maintenance convenience of the cutting machine.

3. Current Status of Modular Design Research

At present, "modular appearance design" is mostly used in the design and production of furniture products, and its application in mechanical processing products is relatively limited. Due to the fact that the appearance of polyurethane sponge cutting machines is mostly composed of columns, beams, knife holders, etc., the concept of "modular design" is inevitably introduced in the design process of the appearance of polyurethane sponge cutting machines. Modular design refers to combining certain elements of a product together to form a subsystem with specific functions. Using this subsystem as a universal module and combining it with other product elements in various ways to form a new system, generating a series of products with different functions or the same function but different performance. IKEA has designed a "modular" furniture design approach, where furniture is assembled into separate parts and products are divided into different modules that can be designed in blocks.

Helina focuses on the three key issues involved in module partitioning: partitioning principles, partitioning angles, and clustering methods, and conducts systematic research based on previous achievements to provide guidance for modular partitioning of different products. Zhang Meng proposed a method for preliminary modular division of mechanical products based on various correlation relationships between complex mechanical product components. The minimum and maximum divisions were calculated, and components with close correlation relationships were placed into the same maximum division to form a preliminary module. The final result of module division was determined through fuzzy clustering analysis of the minimum division subsets within the module. Liu Jiqing proposed a multi strategy modular division scheme for electromechanical products using the quality function deployment method to solve the contradictions between the three strategies of technological evolution, customization, and generalization in the development process of electromechanical products. Foreign scholars have proposed three modular partitioning methods: "top-down" and "bottom-up" service module partitioning, and "top-level D" based physical module partitioning. The commonly used module partitioning methods currently include: modular partitioning method for product lifecycle; Modular partitioning method based on product functionality; There are three modular partitioning methods based on product structure. In summary, with the continuous improvement of customers' requirements for various aspects of the product, modular design of the product is very necessary. However, overall, the application of modular design in mechanical equipment and ordinary household products is conducive to efficient structural design and appearance innovation of products.

4. Optimization of Appearance Structure of Polyurethane Sponge Cutting Machine

4.1. Human Machine Engineering Optimization

The core of the structural design of mechanical products operated by humans should be to take the user as the foundation, innovate around the comfort and convenience of the "user" on the basis of meeting product functions, and improve work efficiency. The existing gantry style polyurethane sponge cutting machines are mostly designed based on the size of the produced polyurethane sponge, and their height is not suitable for most operators. Operators cannot operate in the optimal standing posture, which will inevitably affect the user's work efficiency. The control panel of the common gantry style polyurethane sponge cutting machine is located inside the crossbeam. When designing the height of the product and the height of the control panel, the median body size of the male population can be used as a reference. According to the relevant measurement parameters of ergonomics specified in the national standard GB10000-88, and on the basis of ensuring the functionality and safety of sponge cutting machine products, optimized design is carried out to enable workers to maintain the most comfortable operating posture during the processing and screen operation. Therefore, the following formula is designed:

$$H=P(SG+SB+QB) +G(CX+CZ+ZS)$$

In the formula, H is the minimum functional size of the polyurethane sponge cutting machine, P is the human body size (SG is height, SB is upper arm length, QB is forearm length), G is the functional correction amount (CX is shoe wearing correction amount, CZ is operation correction amount, ZS is posture correction amount).

The correction amount for wearing shoes takes into account factors such as height, eye height, shoulder height, elbow height, and hand function. The correction amount is:+ 23 cm.

Considering the forward extension of the upper limb, the correction amount for the operation is:- 10 cm.

The posture correction amount takes into account the user's standing height, eye height, shoulder height, elbow height, etc. in product design, with a correction amount of -8 cm.

Therefore, the minimum functional size for the height of the polyurethane sponge cutting machine was measured to be 2188 mm. In actual production, the actual height design of the sponge cutting machine is reasonable within the range of 2100-2200 mm.

4.2. Modular appearance structure optimization of crossbeam

For complex products, modular analysis can simplify them. When designing the structure of the polyurethane sponge cutting machine crossbeam, it is necessary to fully consider the rigidity and stability requirements of the cutting machine for the crossbeam. Design operation buttons, lighting fixtures, etc. in product design to incorporate ergonomics. For the optimization of the operation buttons on the crossbeam, the buttons can be independently designed to facilitate unified operation by users and improve the safety performance of the product. In terms of overall design, change the appearance structure of the crossbeam body and design it as a trapezoidal structure (Figure 1). And embedded lighting fixtures are installed at the top of the crossbeam, enriching the outer surface of the crossbeam through concave convex or rough designs, increasing turning changes, and creating visual jumps.

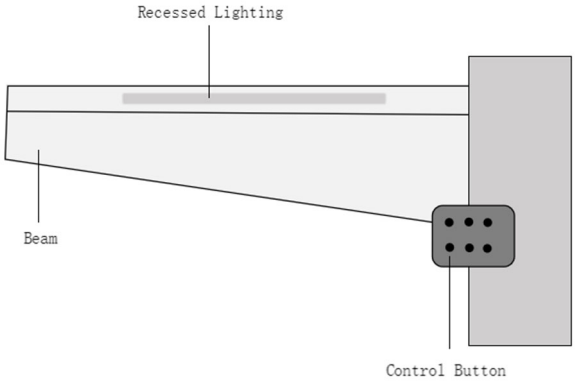

Figure 1. Structural optimization of crossbeam

4.3. Modular appearance structure optimization of columns

The column mainly plays a role in supporting the crossbeam and connecting other key components in the structure of the polyurethane cutting machine. In the design of columns, their pillars often receive people's attention first, but the design of the connections between columns, other beams, and other components is also crucial. In the design of the pillar (Figure 2), the overall shape of the pillar is highlighted, and multiple equidistant heat dissipation holes with internal depressions are set on the pillar to enhance aesthetics while ensuring heat dissipation function. For the turning points between columns and other parts, a small rounded corner design can be used to avoid safety hazards caused by overly sharp corners. In terms of materials, it is necessary to improve processing techniques such as painting, welding, and casting, in order to meet the diverse design requirements of columns, improve product quality, and extend product durability.

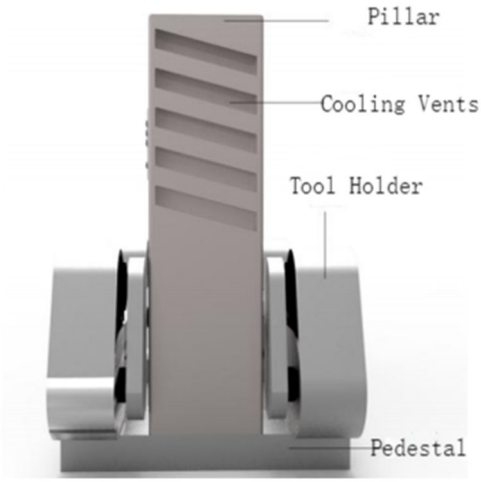

Figure 2. Structural optimization of crossbeam

5. Modular Structure Optimization Analysis of Polyurethane Cutting Machine

The side view of the column structure in this renovation is a regular rectangle, and the front view is a trapezoid, referring to the style of Roman columns. It is narrow at the top and wide at the bottom, with clear lines and an overall elegant and generous appearance. The structure is stable, greatly increasing the stability of the polyurethane sponge cutting machine during operation and enhancing its safety performance. The rectangular sliding rail structure designed on the pillar not only meets the appearance requirements but also ensures the connection with the tool holder. The heat dissipation holes designed on the outer side of the slide rail can effectively dissipate the heat generated during the friction between the slide rail and the blade with the sharpening stone in a timely manner, increasing the service life of the machine. The main form of the crossbeam in this design renovation is a right angled trapezoid, which visually has a certain degree of activity and breaks the oppressive feeling brought by the traditional rectangular design. The embedded lighting structure on the upper part of the crossbeam solves the problem of unsightly appearance of the original exposed lighting and reduces the problem of external lighting being damaged due to collisions during operation. The integrated operation panel designed at the lower end of the crossbeam changes the original decentralized layout, making it more convenient for users to operate. Compared with the dispersed exposed operation buttons, the centralized operation panel has a certain aesthetic appeal visually. The design of the operation panel reflects the requirements of ergonomics while enhancing aesthetics, providing users of polyurethane cutting machines with a better operating experience.

6. Conclusion

Traditional polyurethane sponge cutting machines focus more on functional improvements and neglect structural improvements in appearance. At present, the appearance of polyurethane cutting machine products is generally simple, the structural design is unreasonable, and the convenience of users during operation is not fully considered in the design.

The appearance lacks beauty and can even affect the safety performance of polyurethane sponge cutting machines. Based on ergonomics, this article studies the height of polyurethane sponge cutting machine and ultimately determines that the height of the cutting machine product is 2100-2200 mm, which is the most suitable height for operation. Based on modular division in the design of the appearance structure, the crossbeam and column of the polyurethane sponge cutting machine are structurally optimized. The final designed product has high aesthetics, is easy for users to operate, and to some extent improves product safety, enhancing the competitiveness of the product in the market.

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