

Research on Structural Optimization of Longmen Polyurethane Sponge Cutting Machine

Weiwei Wang^{1,*}

¹Zhejiang Wangjia Fengfan Sponge Products Co., Ltd. Jiaxing 314000, Zhejiang, China

*Corresponding author: Weiwei WANG (Email: 3323872951@qq.com)

Abstract

Polyurethane sponge has excellent properties and is widely used in industries such as automotive, medical, and furniture. With the development of society, the demand for polyurethane sponge in China has been increasing year by year. However, the efficiency of polyurethane sponge cutting machines in China is currently low and there is no advantage in market competition. Taking the most common and widely used circular blade sponge cutting machine as the research object, it was found that the current circular blade sponge cutting machine has the problem of one-way cutting, which leads to half of the time the machine is idling and low work efficiency. Therefore, based on this issue, this article discusses the current research status and structural working principle of polyurethane sponge cutting machines. Three structural improvement schemes are proposed to address the problem of low work efficiency of circular blade sponge cutting machines for technological innovation. The weight assignment evaluation method is used to evaluate the three structural improvement schemes from multiple perspectives such as feasibility and aesthetics. Finally, it is determined that adding a set of cutting blades in the middle of the cutting machine column to increase work efficiency is the most suitable technical transformation scheme. By optimizing the structure of the polyurethane sponge cutting machine, it is beneficial to improve its working efficiency, enhance its competitive advantage in the market, and provide a theoretical basis for the innovative research and development of polyurethane sponge cutting machines in the future.

Keywords

Sponge cutting machine, double-layer blade structure, label weight, structure optimization.

1. INTRODUCTION

The introduction should provide background information (including relevant references) and should indicate the purpose of the manuscript. Cite relevant work by others, including research outside your company. Place your work in perspective by referring to other research papers. Inclusion of statements at the end of the introduction regarding the organization of the manuscript can be helpful to the reader.

Polyurethane sponge has rich pore structure, large surface area, and excellent elasticity. In addition, the production cost of polyurethane sponge is relatively low, so it can be found in both daily life and extreme environments. Due to the difference in elasticity between high and low elasticity of polyurethane sponge, it is widely used in the production of products such as sofas and mattresses. Due to its ability to withstand low temperatures ranging from -50 °C to -70 °C, polyurethane sponge is often used as insulation material in Arctic exploration machinery. In

addition, polyurethane sponge exhibits excellent ozone resistance and antibacterial properties, and has good application effects in many complex environments. With the increasing demand for polyurethane sea surface in different fields, polyurethane sponge needs to be processed into different shapes to meet different needs, which puts higher demands on sponge cutting machines.

At present, there is still a certain gap between China's polyurethane sponge cutting machine and some developed countries. Overall, the transformation of polyurethane sponge cutting machines needs to pay attention to the scientific and reasonable application of new technologies, improve work efficiency, and consider the relationship between humans and machines. Compared with developed countries, the advantage of China's polyamide sponge cutting machine lies in its high cost-effectiveness. Due to the increasing investment in the domestic machinery industry, the product performance of polyamide sponge cutting machines is constantly improving. However, the biggest challenge currently faced is the continuous increase in demand for polyurethane sponge in the domestic production industry, and the production capacity using domestic cutting machines is far from keeping up with social demand. Therefore, it is necessary to continuously extend workers' working hours to increase production capacity. In terms of the functionality of polyurethane sponge cutting machines, domestic polyurethane cutting machines can only perform unidirectional cutting motion during operation. After the first cutting activity is completed, the cutting machine needs to return to the starting position for the next cutting, which seriously wastes time and manpower costs.

Based on this, this article takes the gantry style circular blade polyurethane sponge cutting machine as the research object, and aims to optimize the structure of the cutting machine to address the problems of blade idle and low efficiency in current sponge cutting machines. The goal is to propose an optimized structure with the best effect and easy implementation.

2. RESEARCH STATUS OF POLYURETHANE SPONGE CUTTING MACHINE

With the development of science and technology, countries are paying more and more attention to the progressiveness and innovation of industrial machinery. In terms of polyurethane sponge cutting equipment, the data of global cutting equipment has increased dramatically in recent years, with the market share of developed countries such as the United States and Japan reaching 25%, taking a leading position in the global market. China's sponge cutting equipment has a significant advantage in the domestic market due to its low price and high cost-effectiveness. Overall, there are functional deficiencies in China's sponge cutting machine products compared to those in the United States. Japanese sponge cutting machine products have weak competitiveness in the international market competition. Therefore, more research and improvement are needed on sponge cutting machines, utilizing advanced scientific technology to further enhance their labor efficiency.

At present, polyurethane sponge cutting machines in China are mainly divided into two categories: manual and CNC sponge cutting machines. Manual sponge cutting machines have the advantage of low cost, but there are problems of cumbersome operation and low efficiency in actual operation, and manual sponge cutting machines are difficult to cut complex sponge structures. Compared to manual sponge cutting machines, CNC sponge cutting machines are easier to operate, have a higher degree of automation, and are easy for operators to learn and use. According to the overall structure, it can be classified into "open style", "gantry style", "Γ style", etc. Different cutting machines have different cutting layouts, and different cutting methods are used to cut the sponge into different shapes of polyurethane sponge. The open sponge cutting machine has an open cutting area, unlimited cutting range, and fast cutting speed, making it suitable for cutting large sponges. However, its cutting accuracy is relatively low, making it less suitable for cutting tasks that require high precision. The "Γ - type" cutting

machine has a compact structure and occupies a small space, but it is also not suitable for high-precision cutting tasks. The gantry cutting machine is suitable for heavy-duty cutting due to its stable structure and good rigidity. At the same time, it has high cutting accuracy and can meet the requirements of precision cutting. However, increasing the length of the cutting spindle is a prerequisite for meeting the high-precision requirements of cutting, which can lead to the complexity of the structure of the cutting machine. In addition, the cutting speed and efficiency of the gantry type cutting machine are slow, so the research on the gantry type polyurethane sponge cutting machine is aimed at improving its practicality and work efficiency, in order to enhance its production efficiency and competitiveness in the market.

3. STRUCTURE AND WORKING PRINCIPLE OF POLYURETHANE SPONGE CUTTING MACHINE

By analyzing the blade shape and cutting form of the current gantry polyurethane sponge cutting machine, and considering the existing problems of cutting form and pain point analysis, this article focuses on the research of the circular blade horizontal sheet cutting machine. The blade of the circular blade cutting machine relies on a transmission mechanism to quickly cut raw materials, but the blade is prone to wear and tear during operation, reducing its service life. In order to ensure the safe, stable, and efficient continuous operation of the blade, a sharpening stone is installed inside the knife holder to constantly polish the blade and maintain its sharpness. However, during the polishing process, the friction between the blade and the sharpening stone generates heat that cannot be dissipated in a timely manner, which can pose a certain safety hazard. In addition, the crossbeam and column of the circular blade cutting machine maintain a smaller contact length, which can bear more internal space loads. The bending moments in both directions on the crossbeam improve the stability and rigidity of the overall structure of the cutting equipment, and enhance the load-bearing effect. At present, although the circular blade cutting machine has a certain numerical control structure, the degree of automation is relatively low, and further improvement is needed for the automation operation components of the cutting machine [4].

The gantry style polyurethane sponge cutting machine places the polyurethane sponge material to be cut on the workbench during operation, and cuts it by inputting cutting parameters into the control system. Before cutting, make the knife holder tightly adhere to the raw material, and then the transmission structure controls the high-speed rotation of the annular blade to cut the sponge. Due to the elasticity of the sponge, it needs to be compressed with a roller to ensure effective cutting of the sponge by the tool holder. In addition, the current level of automation in machinery is relatively low, and manual collection of the cut sponge is required during the cutting process, which seriously wastes manpower. The polyurethane sponge cutting machine can only move in one direction during the cutting process, resulting in the need for the machine to return to the starting point for the next polyurethane sponge cutting after completing one cut. During the back and forth movement, only one cut can be made to the sponge, leading to low processing efficiency and increased production costs.

4. TECHNICAL IMPROVEMENT OF POLYURETHANE SPONGE CUTTING MACHINE

Based on the problem of low efficiency caused by the reciprocating motion of the blade due to the single cutting motion of the blade in the existing horizontal cutting machine, we have adopted a new solution to innovate and improve it.

Firstly, increase the number of cutting blades in the cutting machine to improve its cutting efficiency. Set up sliding rails on both sides of the cutting machine column, and control the up and down movement of different groups of knife holders through the sliding rails. With the

reasonable arrangement of the two knife holders, the cutting equipment can achieve automatic back and forth uniform motion. Under the same cutting time, the cutting efficiency can be doubled. This scheme has a simple structure and principle. When one set of knife holders is used for cutting work, the other set of knife holders is at the top of the slide rail and works alternately, which has a relatively small impact on the accuracy of sponge cutting.

Another improvement plan is to add a blade holder group, but unlike the previous plan, it requires the installation of sliding rails on both sides of the support column. Two sets of annular blades are set in the middle position of the pillar, with opposite directions. Adding a shift structure to the control system of the conveyor belt can control the direction of blade movement and cutting direction through a shift control device. By combining the different movement directions and cutting directions of two blades with their up and down movements, cutting can be carried out alternately. Compared with the previous scheme, the improvement in work efficiency is not significant, but it can significantly reduce the workspace. Similarly, this approach increases the complexity of the internal structure of the cutting machine, making it more difficult to maintain the product in the event of mechanical failure.

The third option does not increase the number of blades, but replaces single-sided blades with double-sided blades to improve work efficiency. At the same time as replacing the blade, it is necessary to add a double-sided sharpening stone structure on the original cutting unit components, which can continuously polish the inner and outer blades through the double-sided sharpening stones to meet the sharper blade strength. This scheme has a simple design and low difficulty in modification, but it requires high quality of the blade. Under this scheme, the wear and tear of the blades increases, and the blades need to be replaced frequently. Further development of more sturdy and durable blades is needed to adapt to the modification of this scheme. In addition, the constant friction between the blade and sharpening stone during work can easily generate high heat, so further research is needed on the safety of the cutting machine and the loss of sponge during the cutting process [4].

5. EVALUATION OF DIFFERENT TECHNICAL TRANSFORMATION PLANS FOR CUTTING MACHINES

The three proposed technological transformation schemes for the cutting machine can significantly improve the low efficiency of the cutting machine and completely solve the problem of blade idling caused by reciprocating motion during the operation of traditional cutting machines. However, each of the three schemes has its own advantages and disadvantages. Therefore, based on the applicability of the cutting machine, the efficiency, safety, possibility, and success rate of the transformation, different transformation schemes for the cutting machine will be evaluated, and the optimal scheme will be selected for in-depth research. In order to make the evaluation results more scientifically credible, label weighting is used to evaluate different transformation schemes [6]. By assigning weights to seven aspects of the polyurethane sponge cutting machine, including practicality, aesthetics, safety, work efficiency, ease of maintenance, durability, and feasibility. And the evaluation process and results can be provided to users in need, so that people with different needs can choose the suitable sponge cutting machine based on the evaluation situation. Table 1 shows the specific evaluation of the three options. According to the results of the weight label data, it can be seen that the second scheme has more advantages compared to the other two schemes, which can significantly reduce the workspace, occupy a small area, and have a beautiful appearance. However, in terms of maintenance and the complexity of the transformation, it is more difficult compared to the first solution, and further research is needed on the complex process structure of the cutting machine in subsequent studies.

Table 1. Evaluation of Weight Assignment for Cutting Machine Technical Transformation Plan

		Option					
		1		2		3	
Weight Criteria	Weight	Weight Score	Rating Score	Weight Score	Rating Score	Weight Score	Rating Score
Practicality	15%	3	0.45	4	0.6	3	0.45
Aesthetics	10%	3	0.3	4	0.4	5	0.5
Safety	20%	3	0.6	3	0.6	2	0.4
Work Efficiency	25%	3	0.75	3	0.75	3	0.75
Ease of Maintenance	10%	4	0.4	3	0.3	3	0.3
Durability	10%	3	0.3	3	0.3	2	0.2
Feasibility	10%	4	0.4	4	0.4	3	0.3
Total Score		3.2		3.35		2.9	

6. CONCLUSION

By investigating the models and categories of polyurethane sponge cutting machines currently on the market, the advantages and disadvantages of each model of sponge cutting machine product were clarified, and it was determined to carry out research on gantry polyurethane sponge. Through comprehensive analysis, the working principle of the existing gantry polyurethane cutting machine products is clarified, and based on the structural and functional analysis of the products, the defects of the existing circular blade sponge cutting machine are pointed out. In response to the problem of low production efficiency caused by half of the time when the existing wake-up blade sponge cutting machine is idle during operation, three solutions have been proposed by improving the structure of the sponge cutting machine to solve the above problems. By evaluating the weight assignment of three schemes, in the three technical improvement schemes, a set of cutting blades were added in the middle of the column of the cutting machine, and the gear adjustment device was used to adjust the up and down of the two blades. The alternating work of the blades greatly increased the working efficiency of the polyurethane sponge cutting machine. At the same time, due to the added blades being on the inner side of the column, the structural improvement of this method will not increase the space of the cutting machine. However, it will increase the complexity of the sponge cutting machine structure, making it difficult to repair the cutting machine in the event of a malfunction.

REFERENCES

- [1] James Sternberg, Olivia Sequerth, Srikanth Pilla. Structure-property relationships in flexible and rigid lignin-derived polyurethane foams: A review [J]. *Materials Today Sustainability*, 2023, 100643.
- [2] Albert J. Shih, Chengyong Wang. Advances in machining of hard tissues—From material removal mechanisms to tooling solutions [J]. *International Journal of Machine Tools and Manufacture*, 2022, 103838.
- [3] Zhang Rongbao Application and Trend Research of Mechanical Structure Optimization Design [J]. *Equipment Management and Maintenance* 2019(18): 86-87.
- [4] Jin Geliang Structural Optimization Design of Longmen Laser Cutting Machine [D]. Dalian Jiaotong University, two thousand and nineteen

- [5] Peng Zongyuan, Design Issues of Mechatronics Products [J]. Mechanical Management Development, 2016(10): 31-33.
- [6] Chen Pengyu, Li Qing The monotonicity test of weight in technology evaluation methods from the perspective of relative evaluation: based on the correlation coefficient method [J]. Journal of Xihua University (Philosophy and Social Sciences Edition) 2020(06): 100-110.C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.