Optimized Design of Candle Conveying Line Based on TRIZ Theory

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Abstract. In view of the problems of large areas, many pieces of equipment, and high manufacturing cost in the present candle conveying line, a new type of conveying line is determined by using TRIZ theory. By using the contradiction method and material field analysis method, a kind of coaxial bidirectional drive transmission line structure is designed. The candle conveying line designed by TRIZ theory has the advantages of a compact structure, a small floor area, and lower cost.

Keywords: Optimised Design, Candle Conveying Line, TRIZ Theory

1 Introduction

TRIZ (Theory of Inventive Problem Solving) theory is the theory of solving the problem of invention, which originated in the former Soviet Union. It was invented by Inventor G.S. Altshuller's team, as a theoretical approach to rapid technological innovation by studying millions of patents [1]. In recent years, TRIZ theory has been widely used in the innovative design of mechanical products. Based on TRIZ theory, Wang [2] carried out the innovative design of a gear clamping system; Heng and Luan [3] designed the apple sorting and bagging device; Jiang et al.[4] completed the design of a multi-functional coating device for the pipeline.

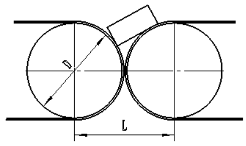
The main function of the candle conveying line is to transport the finished candles to each workstation for packaging. The packaging equipment is installed on both sides of the conveying line. Combined with the TRIZ innovation theory, this paper optimizes the design of a candle conveying line for its high manufacturing cost and large floor area.

2 Description of engineering Problem

The conveying line is one of the main types of automated production lines, and conveyor carriers are divided into rollers, chains, and belts according to the size of the materials. The size of the candle is $\Phi 30 \times 15$ mm, and it belongs to a small block material. The carrier is a belt, and the conveying line is annular. It is composed of two linear belt machines with the same structure and different running direction. A steering device 180° sector bender is installed at both ends of two belt conveyors to ensure the smooth delivery of candles on the entire circular line, as shown in Figure 1. In this design, considering the conveyor belt's allowable strength, additional bending stress, and many other factors, the drum diameter should not be too small. For small materials such as candles, at the joint of the linear belt conveyor and the turning belt conveyor, the accumulation of materials occurs easily, as shown in Figure 2. Therefore, there are many problems in the circular candle conveying lines, such as the large input equipment, high manufacturing cost, material accumulation, and large floor area.

D-drum diameter

Fig. 1. Belt loop conveyor line.



L-drum distance

Fig. 2. Belt loop conveyor line.

3 Preliminary Optimization Scheme

The design of technological systems, which was an art a hundred years ago, is now an exact science, and the essence of TRIZ theory is that it will fundamentally change the process by which new technological ideas are generated. TRIZ innovation theory helps people overcome inertia and accelerate the process of innovative design [5].

3.1 Principles of Optimal Design

The principles of the optimal design of the candle packing and conveying line are as follows: (1) making the whole conveying line occupy less land and investing less equipment to meet the normal transportation of candles; (2) making sure that the materials do not accumulate and scatter, and has the advantages of simple structure, low manufacturing cost, and easy maintenance.

3.2 Preliminary Optimization Plan

TRIZ theoretical system tailoring eliminates the negative functions generated by the tailoring part and reduces the cost, while the useful functions performed still exist [5]. In the present candle packing conveying line, the main conveying function is the two linear belt lines, while the bender only plays the role of transition and steering, the manufacturing cost is a little higher, and the floor area is large. According to the system cutting method, two 180° sector bends are cut, which reduces not only the number of equipment but also the floor area and the manufacturing cost.

4 Systematic Analysis of TRIZ Theory

The function analysis method is an important analysis method of TRIZ theory, which aims to analyze the current technical system, supersystem components, and the function relationship among them [5]. Its main purpose is to decompose the existing system, to determine the main functions provided by the technical system, to clarify the useful functions of each component and its contribution to the system functions, and to find the breakthrough point to solve the problems, create and draw component function model diagram [4]. The initial optimization scheme of the candle conveying line is the current technical system. The current technical system consists of the control system, roller, rack, belt, motor, bearing parts, belt distance, the conveying material (candle), and the control system, which is a supersystem, and the acting object of the system is the conveying material (candle). The functional model established is shown in Figure 3.

Through the functional analysis of the components, it is found that the distance between the two belts hinders the normal steering of the candles, which is a harmful function; the frame and bearing parts are the fundamental reasons for the large gap between the two belt conveyor, which is a lack of function.

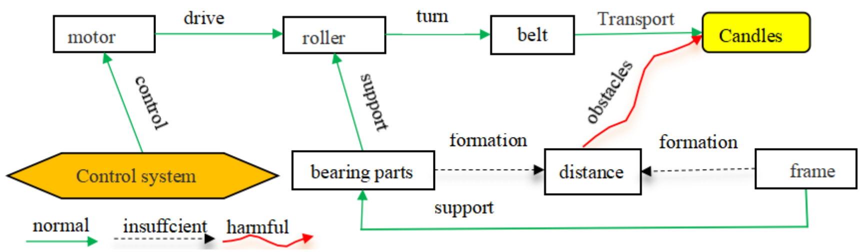


Fig. 3. Functional model diagram.

5 TRIZ theory to Improve the Scheme

5.1 The Law of Technical Contradiction

Technical contradiction refers to the improvement of one engineering parameter of the current technical system, which may lead to the deterioration of another parameter. This contradiction is called technical contradiction [7]. Through the analysis of the function model, it can be concluded that reducing the distance between the two linear belt conveyors can ensure the smooth transition of the candle transportation and avoid the phenomenon of throwing material. At the same time, it can reduce the size of the frame and the bearing parts, which is in contradiction with the simple structure of the conveying line and the low manufacturing cost. The above problems are transformed into technical contradictions described by 39 parameters in TRIZ theory. The improved parameters are 33 Operability, 35 adaptability and versatility, 34 maintainability, and 32 manufacturability.

Table 1. Table of contradiction matrix.

Parameters for Improvement	The Parameters of Deterioration: 32Manufacturability
33 Operability	Principles of innovation: 2, 5, 12
35 Adaptability and versatility	Principles of innovation: 1, 13, 31
34 Maintainability	Principles of innovation: 1, 35, 11, 10

After transforming the concrete problem into a concrete contradiction matrix, we use the contradiction matrix to solve the problem [5], look up the Ács Schuler contradiction matrix, and get nine innovative principles to solve the problem, as shown in Table 1.

Through the analysis, it is found that the combination principle of Innovation Principle 5, the separation principle of Innovation Principle 1, Pre-compensation Principle 11, and the extraction principle of the original new Principle 2 are of practical significance for solving the current problems, as shown in Table 2. According to the extraction principle, the combination principle, and the separation principle, the solution to the technical contradiction is as follows:

Table 2. Principles of innovation.

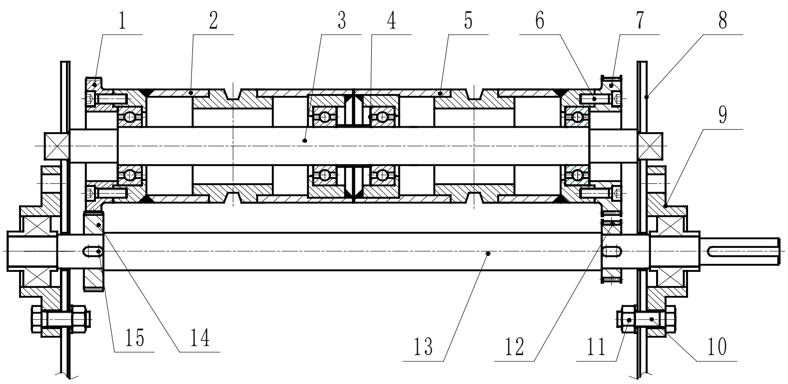
NO	Principles of Innovation	The Meaning of TRIZ
1	Dividing Principle	Dividing an object into parts that are easy to assemble
2	Principle of Extraction	Extracting a negatively impacted part or property from an object.
5	Merger Principle	Merging operations of the same class together spatially or temporally.
11	Pre-compensation Principle	The lower reliability of the object is compensated by pre-prepared measures.

According to Extraction Principle 2, the two racks and the bearing parts adjacent to the inner side of the belt conveyor are removed.

According to the Merging Principle 5, the drum, frame, and roller shaft of two belt conveyors with opposite conveying directions are combined together. Fixed pallets are installed inside the bracket, and two conveyor belts are arranged side by side on the pallets. In order to prevent friction between belts, the distance between conveyor belts is only 5 mm.

According to Dividing Principle 1, the original driving roller of a belt conveyor is assembled by the shaft, the bearing, and the roller body. The roller body consists of two parts.

According to the principle of Pre-action 11, under the active roller, a drive shaft is added, as shown in Figure 4. At the same time, the structure of the drum body is improved by installing a gear on the left-rotating drum body and a synchronous belt pulley on the right-rotating drum body. The motor drives the shaft of the intermediate transmission device to rotate. When the rotation torque is transmitted to the right drum through the synchronous belt, the direction of rotation is the same as that of the motor, and when it is transmitted to the left drum through the gear meshing drive, the direction of rotation is the opposite to that of the motor.



1-large gear; 2-left rotating drum body; 3-drive drum shaft; 4-bearing; 5-right rotating drum body; 6-cylindrical head bolt countersunk head screw; 7-large synchronous pulley 8-support plate;
9-bearing block; 10-connection bolt; 11-nut; 12-small synchronous pulley; 13-shaft; 14-pinion; 15-key

Fig. 4. Functional model diagram.

5.2 The law of Physical Contradiction

Physical contradiction means that in order to implement some function, mutual exclusion is required for the same parameter of the same object [7]. The belt conveyor's active drum position should be chosen in the loose side tension of the position of both discharge ends to ensure that the load-bearing section always has a tight edge. After adopting the innovative combination principle and the pre-compensation principle, the two rollers are driven by a motor. Thus, when the two belt drives are working, there will always be a loose bearing section of the conveyor belt. Therefore, there are physical contradictions: for the right-running belt conveyor, the belt-carrying end is the tight edge; for the left-running belt conveyor, the belt-carrying end is still the tight edge, and the tight edge is running to the left and right to run.

In order to solve this problem, the space separation principle is adopted by changing the position of the active drum, changing the head drive to the Middle Drive, and adopting the back-to-empty belt surface drive. Regardless of whether the belt conveyor travels right or left, it is necessary to always ensure that the carrying section is tightly edged, which avoids the phenomenon of conveyor belt slipping when conveying, and is convenient for layout and maintenance.

5.3 Material Field Analysis

TRIZ theory uses matter and field to describe system problems. It is called Matter-field analysis [7].

After the position of the driving drum is moved to the middle position of the belt conveyor, the surrounding angle of the driving drum is too small, and there is not enough tension to ensure the normal operation of the conveyor belt. Then, the object field analysis method is used to solve the problem.

The material field model of the current system is as follows: the workpiece S1 is the belt, the tool S2 is the active roller, and the interaction field F1 is the mechanical field. The active roller's enclosing angle is too small, and the conveyor belt can not obtain enough tension. Therefore, it belongs to the non-efficient complete model, as shown in Figure 5. According to the standard solution 1.1.3 of material field analysis [6], a material S3 is added outside S2 to improve the useful effect of the active roller, as shown in Figure 6.

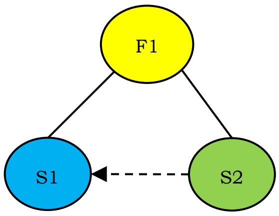


Fig. 5. Model of the physical field.

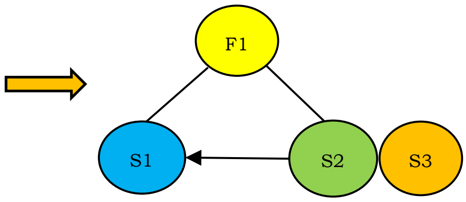


Fig. 6. Standard Solution 1.1.3 model.

According to the Standard Solution Model 1.1.3, a redirection roller is added on both sides of the active roller, which increases the surrounding angle of the active roller, increases the tension of the conveyor belt, and ensures the normal operation of the conveyor belt.

5.4 Smart Little People

In TRIZ theory, the *smart little people* method is used to achieve the desired function, and the structure is redesigned according to the *smart little people* method [7]. In order to ensure that the delivery of candles can turn smoothly, this paper uses the method of smart little people on the belt machine and candles to do further analysis. The yellow figure represents the belt machine running to the left, the pink figure represents the belt machine running to the right, and the brown figure represents the object (candle), as shown in Figure 7. In order to realize the smooth turn of the candle figurine, the green guiding figurine is introduced. The candle figurine is guided by the green figurine to turn to the right-hand belt machine, as shown in Figure 8.

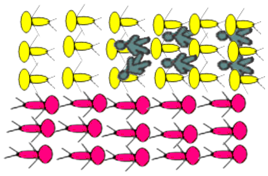


Fig. 7. Conveyor line minion model.

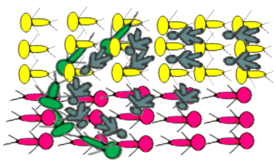


Fig. 8. Improved model of the conveyor line.

According to the *smart little people* method, a guiding device is added at both ends of the head and tail of the two belt conveyors. The guiding device is realized by the synchronous belt, and the two synchronous belt pulleys are installed on the two side racks. Synchronous operation direction and the direction of the belt conveyor form a certain angle, and the synchronous belt is driven by motor drive alone, as shown in Figure 9. The candle, guided by the guide device, is smoothly guided to another belt conveyor.

5.5 Final Solution

Through the application of TRIZ theory, initial optimization plans for reflection are continuously initiated, and the final optimization scheme is formed [4]. The whole ring production consists of two linear belt conveyors, two belt conveyor common frame, supporting plate and other structures, and two active drums by shaft support; under the action of the active drum, a transmission device has been added, which rotates the motor into two different directions of the drum through gear transmission and synchronous belt transmission. The driving device is located in the middle of the belt conveyor and is driven by returning to the empty belt surface, as shown in Figure 9.

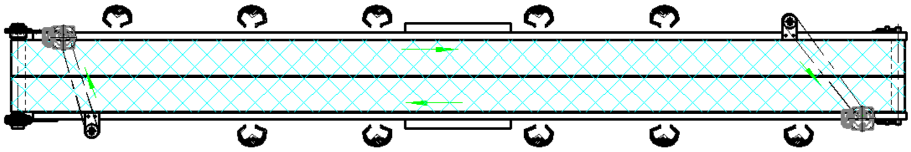


Fig. 9. The final schematic.

6 Conclusion

In this paper, TRIZ theory is used to optimize the design of the candle conveying line for its large area and many pieces of investment equipment. The structure of a two-way belt conveyor line driven by coaxial is determined, and the candle direction is realized by adding a synchronous belt at the end. The distance between the two belts is only 5 mm, which avoids the accumulation of candles. The synchronous belt guiding device is much cheaper than the original turning machine, as shown in Figure 1. The project group has been granted a patent for a utility model, and the transmission line has been put into use in a candle factory in Dandong, Liaoning Province, which has reduced the equipment manufacturing cost by 40% and reduced the floor space occupied by 1/3 for the enterprise. The feasibility of the candle conveying line designed by TRIZ theory is verified by the application of the equipment.

Acknowledgments

This paper is one of the research achievements of the Key Laboratory of Digital Design and Intelligent Manufacturing of Lightweight Castings for New Energy Vehicles Liaoning Provincial. No.: 2022JH13/10200058.

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