Cutter design and multi-objective optimization of machine for cable peeling

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Abstract
Cutter design and multi-objective optimization of machine for cable peeling is proposed to use mechanical peeling instead of manual peeling in this paper. First, the design of the machine for cable peeling includes executive mechanism, driving part for cable, driving part for executive mechanism, and peeling mechanism. Then, the cutting experiment platform is set up to verify the actual effect of cutting, and different cutting depths, cutting speeds and fixing cables methods are discussed by the cutting experiment platform. A numerical simulation method is proposed, and different cutting methods, cutting depths and cutting speeds for cutting different materials are discussed by simulation method. The results show that simultaneous cutting is better than sequential cutting. The results show a good agreement between the results obtained from the finite element modelling and experimental investigations. A theoretical reference is provided for subsequent structural improvement. Finally, multi-objective optimization of machine for cable peeling is realized. The aim of the optimization was improving the dimensional accuracy after cutting and reducing the deformation of the cut surface. Cutter thickness, cutter angle, and cutter material are used as optimization variables, and the final optimal solution is obtained. The cutter is manufactured according to the final optimal solution, experiment of cutting is performed, and good agreements were achieved between optimal solution and experiments. Comparing the final results with the initial results shows a significant improvement.

Keywords: Cable peeling, Structural design, Finite element method, Multi-objective optimization, Cutting energy consumption

1. Introduction
Demand for cables has been increasing in recent years (Pallon et al., 2016; Preuss et al., 2019). As the pillar industry of the national economy, the cable industry is used for broad prospects (Pourrahimi et al., 2018). Cable processing technology has attracted much attention. Peeling, straightening (Gui et al., 2019; Wang et al., 2018; Yu et al., 2018), bending (Anvar et al., 2018; Phocas et al., 2019; Yu et al., 2019) and other processes of the cable are required before using or forming the product. Figure 1 shows a product of cables—the lower lead of a double pole variable fuse. Many manufacturing processes are required for the manufacture of this product, but the most important process is peeling of cables. Currently, manual peeling method is used for cable, this method is low production efficiency, low labor intensive (Yassin et al., 2018) and product qualification rate.

The cable is composed of outer structure of insulation and inner structure of conduction. The outer structure is thick and hard, the inner structure is composed of multiple strands of wire, which are spirally wound around each other. For such structures, such as optical cables, the specific processes are required for peeling of cables. The specific process mainly includes the following three steps: (1) cutting the end; (2) cutting the middle; and (3) peeling insulation.

At present, the commonly used cutting the end methods can be classified into four types: chain sawing (Copur, 2010), slashing cutter (Johnson et al.,2012), reciprocating (Shen et al., 2017) and circular sawing (Momim et al.,2017). Different cutting methods are suitable for different materials, and can achieve different cutting effects. First, chain sawing is used to cut forest product by Shenga et al. (2017) and Romoli (2018). Second, the reciprocating saw is
designed by Alexander et al. (2007). Third, finite element model and experimental platform for circular saw blade cutting system of mulberry cutting machine were established by Meng et al. (2019). Sugarcane harvester is designed by Kroes et al. (1995) and Chen et al. (2016), and slashing cutter and circular sawing are combined in this machine. The cutters are made into different shapes for cutting different materials. For example, peel cutters are used to cut cabbage root (Du et al., 2015) and sugarcane (Xie et al., 2019), and pipe cutters are used to cut multilayered pipe (Chen et al., 2015). Factors such as the energy consumption and the shape of the cut surface for cutting the same material are affected by cutter shape. Such as effects of the energy consumption of three cutting blade designs is compared by Hao et al. (2018), and cutting energy consumption of cutter mounted at different oblique angles is compared by Johnson et al. (2012).

Cutting the middle can be divided into rotary cutting and straight cutting. Rotary multi-cutter device manufactured by Wu et al. was used to cut stainless steel wire ropes (2015). There are also many straight cutting tools (Kaselouris et al., 2017), and their shapes of these tools are different, such as polyhedron (Menezes et al., 2014), spherical (Maas et al., 2017), cylindrical (Lu et al., 2017). In addition, unused materials are stripped differently, for example, brushes are used to peel cassava tubers by Barati et al. (2019), peeling rollers are used on citrus (Pan et al., 2015), and the principle of friction is also used in a kolanut peeling device (Kareem et al., 2014).

In summary, cutting the ends, cutting the middle and peeling off the insulation can be done by many structures, but there is no structure to implement these functions at the same time, and there is no structure for cable peeling. Therefore, in this paper, a machine for cable peeling is designed, and manual peeling is replaced by machines. Section 2 provides structure design of the machine for cable peeling. Experiment of cutting is given in Section 3. Numerical simulation of the machine for cable peeling is described in Section 4. Multi-objective optimizations of the machine for cable peeling are presented in Section 5. Finally, the conclusions are presented in Section 6.

### 2. Structural design of machine for cable peeling

The structure design process is shown in Figure 2. Initially, design requirements are analyzed including technical index and performance requirement. Next, conceptual design and detailed design are carried out. The machine for cable peeling mainly consists of a pair of executive mechanism, two groups of driving part for cable, a pair of driving part
for executive mechanism and two groups of peeling mechanism. The conceptual model design is presented in Figure 3. In this process, the cable is driven to the specified position by driving part for executive mechanism firstly. Secondly, executive mechanism is driven by driving part for executive mechanism to complete ring-cutting and slitting line. Finally, the insulation of the cable is peeled off by peeling mechanism.

Fig. 2 Structural design process: (a) Cutting mode of cutter; (b) Number of cutters; (c) Relative position of cutter; (d) Shape of cutter.
Second, executive mechanism is composed of cutter and knife, where the cutter is used for cutting the end and the knife is used for cutting the middle. Rotary-cutting and reciprocating cutting are compared, and the rotary cutting structure is more complicated, so reciprocating cutting is used as solution of cutting the middle. The design of the cutter mainly considers the following four aspects: (a) Cutting mode of cutter; (b) Number of cutters; (c) Relative position of cutter; and (d) Shape of cutter. Tangent cutting is used on the cutter considering the balance of force. Figure 2 (a) shows the two cutting methods of the cutter, which are tangent cutting and angle cutting. Figure 2 (b) discusses the number of cutters. In order to receive the force uniformly and reduce the stress concentration, the number of cutters is reduced from an infinite number of cutters to a limited number of cutters, and finally to two cutters. The relative positions of the two cutters were compared in Figure 2 (c), which are the different plane and the same plane. Considering the cutter interference and cutter damage, the relative position of the different planes is finally selected. The two cutter shapes were compared in Figure 2 (d), which are arc-shaped and V-shaped. Considering that the machine for cable peeling needs to adapt to multiple types of cables, the V-shape is used as the cutter shape.

Third, driving part for executive mechanism is formed of driving controller for linear, transmission device by sprocket, reducer, etc. Similarly, the driving controller for linear is decelerated by the reducer, and then driven by transmission device by sprocket, and finally executive mechanism is moved up or down. In addition, the servo motors (MSMF42L1U2M; Panasonic, Osaka, Japan) is selected for driving controller for rotary and driving controller for linear to provide sufficient force / torque performance. Fourth, the peeling mechanism includes cylinder for driving and claw for performing.

3. Experiment of cutting

3.1 Materials and methods

The cable used in this test is manufactured in accordance with the State Standard of the People's Republic of China GB-T 14049-2008. In order to reduce the workload of the test, the JKTRYJ-10-35 model cable is mainly used as the test material. The machine for cable peeling used in this paper is manufactured according to the design scheme of Section 2. Actual product of the machine for cable peeling is shown in Figure 4. To precisely control the cutting depth
of the cutter and knife, the origin position sensor is mounted on the driving part for executive mechanism. Photoelectric sensor and displacement encoder are installed in order to accurately control the moving distance of the cable, so that the cable can reach the specified position.

Figure 5 shows the cutting experiment platform, cutting test platform including machine for cable peeling and display controller. Display controller is installed to control the machine for cable peeling. The display controller and the driving controller on the machine for cable peeling (driving controller include driving controller for linear and driving controller for rotary) are connected through the control system, and cutting speed and cutting depth are controlled by the display controller.

Dimensional accuracy is an important indicator to measure the machining quality (Han et al., 2019; Sun et al., 2018), and the dimensional accuracy after cutting will also affect the cable assembly and product aesthetics. Therefore, the dimensional accuracy after cutting is used as an evaluation index to measure the machining quality. In this paper, the dimensional accuracy after cutting is characterized by the axial direction reduction length of cable cutting rear end (represented by the letter $a$) and the radial direction reduction length of cable cutting rear end (represented by the letter $b$).

Traditional measurement tools, such as vernier calipers, cannot accurately measure and evaluate indicators due to irregular cutting surfaces. Therefore, the measurement platform is established to make accurate measurements, and the measurement platform is shown in Figure 6. Measurement platform consisting of 3D scanner and Geomagic Studio software. During the measurement, the cut cable is scanned by the 3D scanner, the data from the 3D scanner is imported into the Geomagic Studio software through the STL file (Alharbi et al., 2016; Latham et al., 2020), and evaluation indicators are accurately measured in Geomagic Studio software.

![Fig. 4. Actual product of machine for cable peeling.](image-url)
Fig. 5 Cutting experiment platform.

Fig. 6 Experimental measuring platform.
3.2 Experiment setup

In order to understand the impact of different cutting factors on cable cutting, the cutting test platform needs to be setup. First, we study the effect of cutting depth on cable cutting. The cutter thickness is 5 mm, the cutter angle is 47 degrees, the cutter material is 40Cr, and the cutting speed is 5m/s. The cutting depth is set as 0.4 mm, 1.0 mm, 1.6 mm, 2.2 mm, 2.8 mm, and 3.4 mm. Three cutting tests were performed for each set of depths, and the final result was taken as the average of the measurements. Secondly, we study the effect of cutting speed on cable cutting. The difference is that the cutting depth is set as 3.4 mm, and the cutting speed is set as 4 m/s, 4.5 m/s, 5 m/s, 5.5 m/s, and 6 m/s. Third, we discuss the effect of different clamping methods of the cable, and the experiment platform of different clamping method are shown in Figure 7. Cable clamping or loosening is controlled by the driving roll on the right side of the machine for cable peeling, and is controlled by the claw on the left side of the machine for cable peeling.

Fig. 7 Experiment platform of different clamping method: (a) Cable clamped at the both ends; (b) Cable clamped at one end and relaxed at the other.

4. Numerical simulation of Cutting System

4.1 Finite element modelling

Cable peeling by cutting is large deformation, so ANSYS/LS-DYNA was selected as a tool for numerical simulation. In addition, the geometric model was constructed by Pro/E software, and the simulation model was obtained by importing the finite element model into Ls-Prepost software. IGES is the intermediate format between the Pro/E and ANSYS/LS-DYNA software, and ANSYS/LS-DYNA and Ls-Prepost are connected by K file. The numerical simulation process is shown in Figure 8.
First, we build the geometric model through Pro/E software. To simulate the cutting process using finite element method, machine for cable peeling is simplified into cutting system, which consists of cutter, knife, and cable. However, according to the State Standard of the People's Republic of China GB-T 14049-2008 and Mechanical industry Standard of the People's Republic of China JB-T 10437-2004, we can be known that the inner core of the cable is made by spirally winding a plurality of wires. If the model of the inner core of the cable is not simplified, the inner multi-core wire is twisted with each other. In principle, the inner core of cable is not cut by the cutter or knife during the cutting process, so the inner multi-core of cable is simplified into a single wire.

Second, we build material models to simulate materials. According to the State Standard of the People's Republic of China GB-T 14049-2008, the inner material of cable is soft copper, the outer material of cable is cross-linked polyethylene. Soft copper uses the bilinear isotropic material model, which is independent of strain rate, where the stress and strain of the material are represented by the slope. Cross-linked polyethylene uses the standard piecewise linear material model, the failure criterion uses a strain failure criterion. This model is related to strain rate and uses the Cowper-Symonds model to consider the effect of strain rate. The relationship with yield stress is as follows:

$$
\sigma_y \left( \epsilon_{eff}^p, \dot{\epsilon}_{eff}^p \right) = \sigma_y \left( \epsilon_{eff}^p \right) \left[ 1 + \left( \frac{\dot{\epsilon}_{eff}^p}{C} \right)^{\frac{1}{p}} \right]^{\frac{1}{p}} 
$$

(1)
In the type: C and P denote the parameters of strain rate; \( \dot{\varepsilon} \) is effective strain rate; \( \sigma_{\text{eff}}^P \) is yield stress without considering strain rate.

In addition, the material of the cutter and knife is 40Cr, and 40Cr uses rigid material model. In order to study the cutting effect of different materials, we choose another power product (ABS plastic). And the ABS plastic uses the plastic kinematic material model, this model is related to strain rate and can be considered for failure, strain rate is considered by Cowper-Symonds model. The material properties of the cutting system are shown in Table 1, and material parameters are provided by Ref. (Meng et al., 2019) and cable manufacturers.

| Material type | Material density [kg/m³] | Elastic modulus [GPa] | Poison's ratio [-] | Yield stress [MPa] | Tangent Modulus [GPa] |
|---------------|--------------------------|-----------------------|-------------------|-------------------|----------------------|
| 40Cr          | 7850                     | 206                   | 0.28              | -                 | -                    |
| 65Mn          | 7850                     | 206                   | 0.3               | -                 | -                    |
| YT15          | 11500                    | 510                   | 0.15              | -                 | -                    |
| Soft copper   | 8920                     | 127                   | 0.33              | 90                | 49                   |
| Cross-lined polyethylene | 925                     | 0.304                 | 0.46              | 15.69             | 28.735               |
| ABS plastic   | 1200                     | 2                     | 0.37              | 50                | 49                   |

Meshing is critical in finite element simulation, selecting the appropriate element size is required according to the actual situation. The total of meshes of the model is 50,710. In addition, “eroding contact” in surface to surface is used between the cutter and the cable, and “eroding contact” in surface to surface is used between the knife and the cable.

In order to understand the inherent laws of the cutting process, we simulate the finite element model by setting different conditions. Firstly, we discussed different cutting methods, which include sequential cutting and simultaneous cutting. The cutter thickness is 5 mm, the cutter angle is 47 degrees, the cutter material is 40Cr, the cutting speed is 5 m/s, and sequential cutting and simultaneous cutting are conducted separately. Secondly, cutting cables of different depths is simulated. The cutter thickness is 5 mm, the cutter angle is 47 degrees, the cutter material is 40Cr, and the cutting speed is 5 m/s. The cutting depth is set as 1.0 mm, 1.6 mm, 2.2 mm, 2.8 mm, and 3.4 mm. Next, different speed cut cables are simulated. The difference from the cutting depth is that the cutting depth is set as 3.4 mm, and the cutting speed is set as 4 m/s, 4.5 m/s, 5 m/s, 5.5 m/s, and 6 m/s. Finally, we performed simulations in different materials, including ABS plastic and cross-linked polyethylene, and the cutter thickness is 5 mm, the cutter angle is 47 degrees, the cutting speed is 5 m/s, the cutter material is 40Cr.

4.2 Results and analysis

Cutting experiments and numerical simulations were performed in order to understand the internal laws and provide references for subsequent structural improvements. The following subsections describe some of the key results.

4.2.1 Different cutting methods

The simulation results of different cutting methods can dynamically show the cutting details of sequential cutting or simultaneous cutting. Figure 9 shows the cutting details and time history curve of hourglass energy of different cutting methods. In Figure 9, the cutting patterns at different moments, the total hourglass energy of the model and the total internal energy of the model can be obtained. It can be calculated that the ratio of the sequential cut model hourglass energy to the total internal energy of the model is 8.3%, and the sequential cut model hourglass energy to the total internal energy is 7.9%, both of which are less than 10%.

Hourglass is an important indicator to measure the reliability of numerical simulation result (Tang et al., 2016). The cable cutting problem can be regarded as a nonlinear finite element problem, which involves large deformations, which easily leads to negative volume and contact penetration. Hourglass control is required in the numerical simulation process, so the simulation results need to be verified. In general, when the ratio of the sequential cutting model hourglass energy to the total internal energy of the model is less than 10% (Zhao et al., 2019), we believe that the simulation results meet the expected simulation goal, and the hourglass energy can effectively control the unit distortion. Therefore, simulation results of sequential and simultaneous cutting are considered reliable, and the simulation process can truly reflect the actual cutting process of the cable.
Figure 10 shows a comparison of two different cutting methods. Figure 10 (a) shows the trend of the cutting force of sequential cutting and simultaneous cutting. In the figure, the cutting force is constantly changing during the cutting process, and the changing trend is also different. The maximum cutting force for sequential cutting is 60.56 N, and the maximum cutting force for simultaneous cutting is 60.90 N. From the change trend of cutting energy consumption in Figure 10 (b), the change of different cutting methods (sequential cutting and simultaneous cutting) is different and cutting successively consumes less energy and longer time. Figure 10 (c) shows the slice diagram of the two cutting methods. The reduction length $a$ of sequential cutting is 2.5610 mm, and the reduction length $b$ is 2.1296 mm. The reduction length $a$ of sequential cutting is 2.3427 mm, and the reduction length $b$ is 2.1150 mm.

By comparison, we can see that the effect achieved by sequential cutting and simultaneous cutting is different. During the cutting process, the cutting energy consumption will increase, the machine vibration will increase, and the working stability of the tool will decrease, so the maximum cutting force and cutting energy consumption need to be reduced. The maximum cutting force values for sequential cutting and simultaneous cutting are similar, the cutting energy consumption of sequential cutting are smaller than those of simultaneous cutting, but the latter takes less time, so the effect of simultaneous cutting is better. More importantly, the reduction length $a$ of the latter is 0.2183 mm smaller than the former; the reduction length $b$ is 0.0146 mm smaller than the former. For the dimensional accuracy, the improvement is considered to be effective. From the above, it can be found that the effect of simultaneous cutting is
better, because the force of the cable is balanced to simultaneous cutting, the time is reduced, the cutting action is reduced, and the cutting efficiency is improved. Therefore, in the subsequent improvement design, we can use simultaneous cutting instead of cutting sequentially.

Fig. 10 Comparison of two different cutting methods: (a) Cutting force; (b) Cutting energy consumption; (c) Slice diagram.

4.2.2 Different cutting depths

Different cutting depths are discussed through cutting experiments and numerical simulations. Figure 11 shows the simulation and experimental results of different cutting depths.

It can be found that the maximum error between the simulation results and the experimental results at different cutting depths is 9.3%, and the experimental results are slightly smaller than the simulation results by calculation. Because all errors between the simulation results and the experimental results are less than 10%, the finite element model is considered to be effective and reasonable. As can be seen in Figure 11, the shape and strain of the cut surface are different for different cutting depths. As the cutting depth increases, the reduction length $a$ and the reduction length $b$ gradually increase, and the more irregular the shape of the cut surface. The cutting depth is in the range of 0.4 mm to 1 mm, and the reduction length $a$ and reduction length $b$ are both 0 mm. Therefore, it can be inferred that the cutting depth is 0 mm to 1 mm or even larger, and the reduction length $a$ and reduction length $b$ are both 0 mm. In this interval, the deformation of the cable becomes a recoverable elastic deformation. With the increase of the cutting depth, a small amount of unrecoverable plastic deformation will gradually appear. When the cutting depth is 1.6 mm, the reduction length $a$ is 1.1246 mm, and the reduction length $b$ is 0.3818 mm. As the cutting depth increases, the greater the deformation of the cable, the worse the dimensional accuracy of the cut surface. Therefore, in the cable cutting process, controlling the cutting depth can be used to improve the dimensional accuracy after cutting and processing quality.
4.2.3 Different cutting speeds

In the process of cable cutting, it is assumed that the cutting speed is very small, and the action between the cutter and the cable is equivalent to extrusion, which affects the effect of cutting. Moreover, the cutter will produce friction in the process of cutting cables. The greater the friction force that resulted in the rougher section after cutting, which will affect the dimensional accuracy. Therefore, the cutting speed is one of the factors that affect the cutting effect. Different cutting speeds are discussed in cutting experiments and numerical simulations. Figure 12 shows the numerical and experimental results of different cutting speeds. Similarly, all errors of different cutting speeds between the simulation results and the experimental results are less than 10%, so the finite element model is considered to be effective and reasonable. The error mainly comes from the manufacturing accuracy error of the cable, tool installation error and the cable are not in the center during the cutting process.

It can be seen that different cutting speeds have different dimensional accuracy after cutting from the figure. Therefore, we can consider that cutting speed is one of the factors that affect the dimensional accuracy after cutting. It can be seen that in the range of cutting speed from 4 m/s to 6 m/s, as the cutting speed increases, the reduction length \( a \) and the reduction length \( b \) gradually decrease from the figure. Therefore, the optimal cutting speed of the machine for cable peeling is 6 m/s or more. In subsequent structural improvements, improved transmission mechanisms or alternative drive methods can be used to improve dimensional accuracy after cutting.
4.2.4 Cutting different materials and different ways of fixing cables

Cutting different materials are discussed in numerical simulations. It can be seen that the cutting morphology, strain change and cut surface effect of cross-linked polyethylene and ABS plastic are not different from the Figure 13. Cut surface of ABS plastic is smoother than the cross-linked polyethylene, and ABS plastic will slightly rise when cutting, but this deformation can be recovered.

Different methods of fixing cables are discussed in cutting experiments. Multiple experiments have shown that there are no fixed laws for different fixing methods of cables, which is an uncertainty factor. Therefore, in order to avoid this problem, the fixture to fix the cable is designed in the subsequent improved design.

5. Multi-objective optimization of machine for cable peeling
5.1 Optimization framework

The optimization was performed using Isight (Dassault System, Waltham, MA)(Mann et al., 2019; Rosle et al., 2019; Wu et al., 2016). Figure 14 shows the optimization flowchart. First, the optimization model for the cable cutting problem is established. Improving the dimensional accuracy after cutting and reducing the deformation of the cut surface are used as optimization goals. The dimensional accuracy after cutting is characterized by the reduction length \( a \) and the reduction length \( b \). The deformation of the cut surface is characterized by the maximum cutting force (represented by the letter \( F_{\text{max}} \)). Three design variables were screened according to the requirements of the optimization goal, including cutter thickness, cutter angle and cutter material (represented by the letter \( h \), \( r \), \( g \), respectively). The range of parameter \( h \) was set as [4mm, 6mm], and the range of parameter \( g \) was set as {40Cr, 65Mn, YT15}. In order to facilitate calculation and sampling, the value of \( s = \tan r \) the cutter angle is used as a physical quantity to measure the size of the cutter angle, and the range of parameter \( s \) was set as [0.90, 1.20]. Therefore, the optimization model can be expressed as:

\[
\begin{align*}
\text{Min} : a \\
\text{Min} : b \\
\text{Min} : F \\
4 \leq h \leq 6 \\
0.90 \leq s \leq 1.20 \\
g \in \{40\text{Cr}, 65\text{Mn}, \text{YT15}\}
\end{align*}
\]

Fig. 14 Optimization flowchart.
Second, experimental design is used to sampling design variables within a sample interval, approximate models between optimization variables and objective function is constructed, and optimization algorithms based on Isight are used to solve. The approximate models are response surface methodology, and approximate models are obtained by Pro/Engineer, ANSYS/LS-DYNA and Ls-Prepost. The experimental design is optimal latin hypercube design, optimization algorithms is NSGA – II. Finally, the pareto optimal solution is obtained, and the final solution is obtained after weighing and comparing.

5.2 Experimental verification and comparison

The final optimal solution is as follows: the cutter thickness is 4.43 mm, the cutter angle is 49 degrees, the material is YT15, the cutting speed is 5 m/s, and the cutting depth is 3.4 mm. In addition, the initial solution is as follows: the cutter thickness is 5 mm, the cutter angle is 47 degrees, the material is 40Cr, the cutting speed is 5 m/s, and the cutting depth is 3.4 mm. The actual cutter is manufactured according to the final optimal solution, experiment of cutting is performed. The simulation results of the final solution are shown in Figure 15. Figure 16 shows the experimental platform of the final optimal solution. To verify the accuracy of the finite element model, the simulation results are compared with the experimental results. In order to know the effect of optimization, the simulation results of the initial solution are compared with the final optimal solution. Table 2 shows the results of the initial solution and the final optimal solution.

As can be seen from Table 2, the error between simulation results and experimental results are both less than 10%, so we can believe the simulation results to be reliable, and the finite element models can be believed. Comparing the simulation results of the final optimal solution with the initial solution shows the reduction length $a$ is reduced by 4.9%, and the reduction length $b$ is reduced by 10.6%. Although the effect is not obvious, the dimensional accuracy after cutting has been greatly improved for the dimensional accuracy problem. In addition, the maximum cutting force of the initial solution is 60.56 N, and the maximum cutting force of the final optimal solution is 41.82 N, the comparison shows that the maximum cutting force of the final optimal solution is 44.8% lower than that of the initial solution, which has a significant increase. In summary, the effect of the final optimal solution is much higher than that of the initial solution.
Fig. 15 Simulation results of the final solution.

Fig. 16 Experiment platform of the final solution.
6. Conclusion

In this paper, we presented a machine of cable peeling that can perform cutting the ends, cutting the middle, and peeling insulation simultaneously, which was using mechanical peeling instead of manual peeling. We designed and tested the machine of cable peeling, and numerically simulated the cutting process. The effects of different cutting methods, cutting depths, cutting speeds, fixing cables methods and cutting different materials are discussed. In addition, the multi-objective optimization design of the machine of cable peeling was carried out, and the final optimal solution is obtained. Comparing the final results with the initial results shows a significant improvement. To perfect the design of the machine of cable peeling, future work will involve uncertainty design optimization, discussion of other influencing factors. This work provides a theoretical reference for the improvement and optimization of subsequent structures, and also provides a research basis for material cutting.

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