Theoretical Study on Drilling Wood to Make Fire and Design of Auxiliary Device

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***Abstract*—Human beings have known the phenomenon of friction for a long time, among which "drilling wood to make fire" is one of the earliest methods to make use of friction. From the point of view of human history, human understanding, use and mastery of fire is the first practice for human beings to understand nature and make use of nature to improve production and life. Drilling wood to make fire is an important symbol of human beings from barbarians to civilization. In this paper, the selection, treatment and fire conditions of "drilling wood for fire" wood material are studied by using tribological theory, and a simple auxiliary device is built to verify the actual friction fire process. In this paper, drilling wood to make fire is raised to the height of scientific research, and drilling wood to make fire is closely related to tribology. After the experiment, the designed simple device can meet the requirements, and the open fire can be produced in the expected time.**

Keywords-Drill Wood to Make Fire; Friction to Make Fire; Fire Device

I. INTRODUCTION

Human understanding, use and mastery of fire is the first practice for human beings to understand nature and make use of nature to improve production and life. The application of fire is of great significance in the history of human civilization[1-2].

Up to now, there have been several methods of making fire[3]. In ancient times, due to the constraints of conditions, people often retained fire to make fire. People use lightning to split the branches of the Mars as a fire to retain for the future. Later, flint fire method, drill wood fire method and convex mirror fire method were invented. Flintman's method of drilling wood fire is the most widely known, but it is also the most difficult method.

The physical principle of drilling wood to make fire is the heat generated by friction, which is essentially the process of converting mechanical energy into internal energy (thermal energy).

In the case of rapid friction, kinetic energy produces a lot of heat energy through the conversion. When the speed of generating heat energy is greater than the external heat dissipation speed of the object, the temperature will continue to rise, and when it reaches the ignition point of wood, it will be able to make a fire. Today's research on drilling wood for fire provides us with a survival skill in extreme environments, at the same time, this paper will drill wood to make fire to the height of scientific research, drilling wood to make fire and tribology closely linked.

In this paper, the selection and treatment of "drill wood to make fire" wood material are studied theoretically by using tribological theory, and a simple auxiliary device is built to verify the actual friction fire process.

II. SELECTION AND TREATMENT OF WOOD MATERIALS

A. *Selection of Wood Materials*

The most primitive tool for drilling wood fire is composed of drill pipe and drill plate. The principle of drilling wood fire is to produce carbonized wood chips and ignite combustible materials by friction between drill pipe and drill plate[4]. According to the above principle, this paper sets the following selection standards of drill pipe and drill pipe:

1) The selection criteria of drill pipe are: high hardness (high air drying density), low moisture content and good wear resistance [5]. Drill pipes require wood with high hardness and good wear resistance.

2) The selection standard of drilling plate is low hardness (low air drying density), low moisture content and poor wear resistance. It is generally believed that when the wood density is in the range of 290~1000kg/m3, the wood carbonization rate decreases with the increase of wood density [6], so it is necessary to select the wood with lower density. Some studies have shown that wood moisture content has almost no effect on wood carbonization rate. However, when the moisture content is very low, the friction coefficient increases with the increase of motion velocity [7], and part of the heat will be lost by water evaporation, so the wood with low moisture content is considered. At the same time, the drill plate needs to be drilled out of a large number of sawdust, forming sawdust accumulation, which is more conducive to fire, so it is necessary to select poor wear resistance.

According to the above standards, this paper comprehensively analyzes the characteristics of five kinds of common wood, such as locust wood, elm wood, pine wood, poplar wood and tung wood, and selects locust wood as drill pipe and poplar wood as drill board.

B. *Treatment of wood*

1) Treatment of drill pipe: one end of the cylindrical drill pipe is cut into a cone with a cone angle of 60° with a manual knife.

2) The production of drilling plate: first of all, the drilling plate is perforated, the hole shape is shown in the following figure, is a "V" structure, and hit in the edge area, so as to ensure that the wood is in full contact with oxygen. The mechanical principle of drilling wood for fire is shown in figure 1.

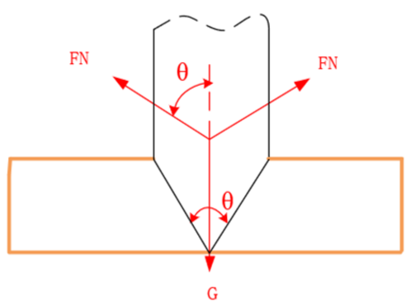

Figure 1. Mechanical principle of drilling wood for fire (θ = 60 °)

III. Fire Condition Analysis

In the vertical direction, according to the principle of force balance:

$$F_N \cos\theta = F + G \quad (1)$$

Here, G is the dead weight of the wooden bit (negligible), F is the positive pressure, F_N is the support of the drill plate to the wooden bit.

Because the error can be ignored, the friction force between the contact surfaces can be equivalent to the force when the height of the cone is 1cm.

$$f_1 = \mu F_N \quad (2)$$

When the sliding velocity does not change the properties of the surface layer, the friction coefficient is almost independent of the sliding velocity. According to the data, the dynamic friction coefficient between wood is 0.25, θ = 60°, F = 100N, and the friction force f_1 is obtained by substituting the above formula.

Friction to do work:

$$W = f1\pi d\ 1 \quad (3)$$

Where t is the rotation time, n is the rotational speed, r is the bit radius, d_1=r. We assume that t = 469s, r = 1.25cm.
The essence of friction heat generation is the process of energy conversion, and the mechanical energy is transformed into internal energy.

$$Q = W\eta \quad (4)$$

Here η is the conversion efficiency, assuming η = 60% [8].

Suppose the distance of heat propagation in wood is d=2cm.

$$m = 0.8d\pi rl \quad (5)$$

$$Q = cm(T - T_0) \quad (6)$$

C is the specific heat capacity of wood, about 1700J/kg ℃, m is the mass of wood at the friction contact interface, and T_0 is the ambient temperature, which is set to 25 ℃.

The contact temperature increases with the increase of friction or rotational speed. When the temperature reaches the ignition point of wood, the wood can burn and drill wood to make fire.

The data showed that the ignition point T of paulownia was about 240 ℃.

The simultaneous formula can calculate that the rotational speed needs to reach about 4.8 r, and the wood can catch fire, thus drilling wood to make fire. The above results will provide some theoretical data support for the design of wood drilling and fire making device.

IV. Construction of Simple Auxiliary Device

A. *Scheme design*

A comprehensive analysis of the ancients' various ways of drilling wood to make fire, they have one thing in common is the use of reciprocating rotational motion. The reciprocating rotational motion can make the friction force between the friction pairs larger than the rotational rotational motion, so the curve reciprocating motion mechanism is designed to realize the reciprocating rotation.

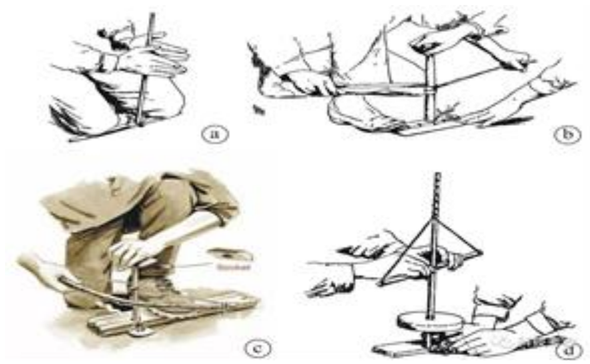

Figure 2. Original method of making fire

B. Structure design

Considering the cost, some of the gears of the device are made of nylon material. In the construction of the console, the console and the ground have a certain height, which is convenient for the experimental personnel to operate.

The simple device is composed of five parts: manual rocker, gearbox, planetary gear train, curve reciprocating motion mechanism and operating table. The rotation angle of the drill pipe driven by the curved reciprocating mechanism in one cycle is 120 °, which is equivalent to 1/3 of the circumference of the drill pipe. According to the theoretical data 4.8r, the rotational speed of the solar wheel 5 connected to the transmission on the planetary gear train

$$n_5=3\times19=14.4r/s$$

Internal gear of planetary gear train Z_6=93, Center wheel Z_5=21, Planetary wheel Z_4=36, Transmission ratio of planetary gear train:

$$i_{56} = (n_5-n_H) / (n_6-n_H) = -Z_4Z_6 / Z_4Z_5 \qquad (7)$$

Of which n_5=57、 n_6=0

The gearbox is composed of gears 2 and 3, gear 2 and manual rocker, gear 3 and tie rod H, Z_3=21、 Z_2=55、 $n_3=n_H$、 n_2=n.

Manual rocker speed:

$$n=(Z_3/Z_2)\times n_3=1r/s$$

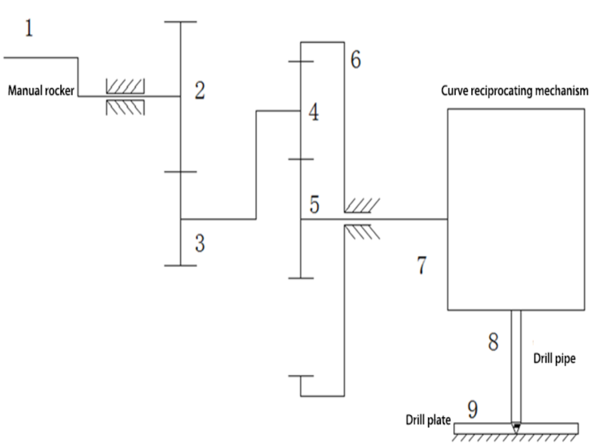

Figure 3. Schematic diagram of the device

C. Auxiliary device machining and assembly

1) Rocker selection

The rocker is a part of input power, which needs to be labor-saving and easy to assemble. The rocker shown in figure 3 meets the above requirements.

Figure 4. Manual rocker

2) Planetary gear train

After calculation, the planetary gear train with modulus m = 1, pressure angle α = 20 °, internal gear Z = 93, center wheel Z = 21, planetary gear Z = 36, transmission ratio 1:4 is selected. The planetary gear train fully meets the requirements.

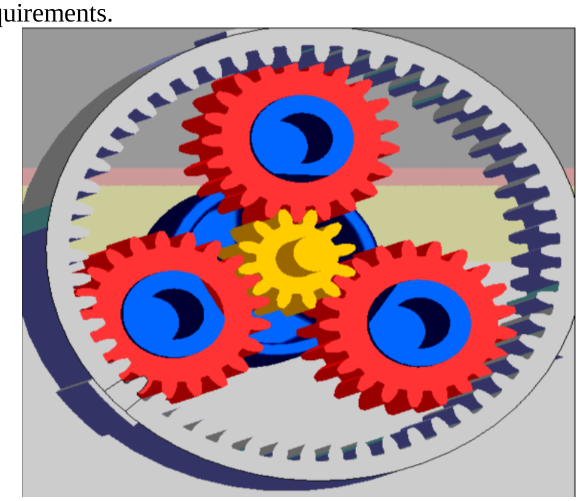

Figure 5. Three-dimensional diagram of planetary gear train

Figure 6. Planetary gear train

3) *Gearbox*

After calculation, the gearbox is made with modulus $m = 1$, pressure angle $\alpha = 20°$, $Z = 55$, $Z = 21$, and the transmission is 1:4.

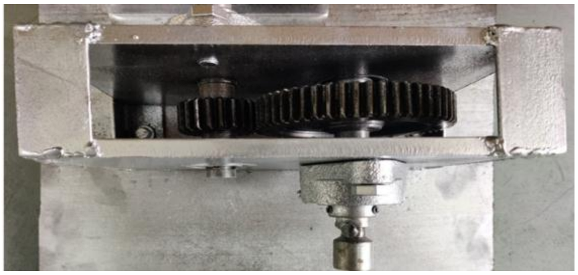

Figure 7. Gearbox

4) *Reciprocating mechanism*

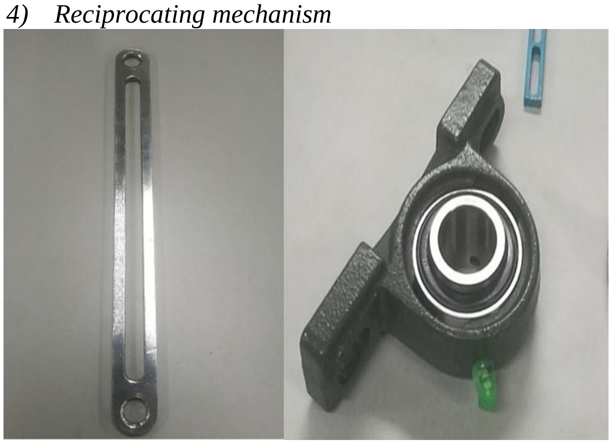

Figure 8. Connecting rod and P205 outer spherical bearing with seat

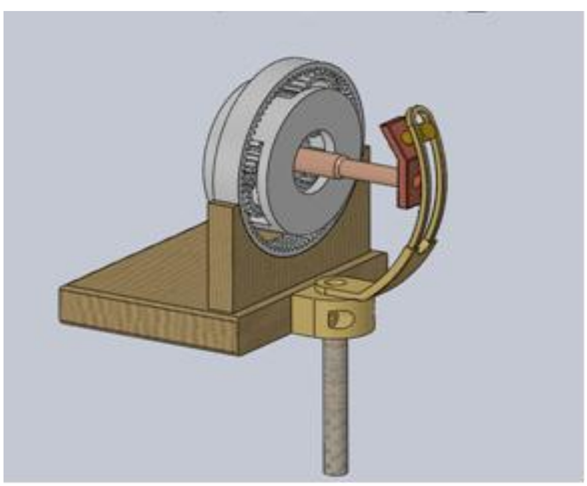

Figure 9. Three-dimensional diagram of curve reciprocating motion mechanism

Figure 10. Physical diagram of curve reciprocating motion mechanism

5) *Overall assembly*

In turn, the manual rocker, the gearbox, the planetary gear train and the curve reciprocating mechanism are installed on the rack according to the predetermined position.

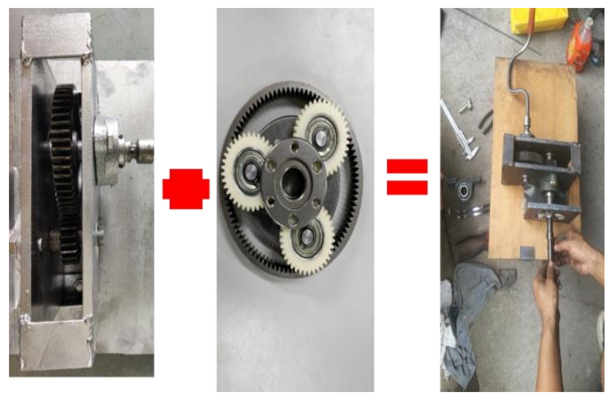

Figure 11. Assembly process

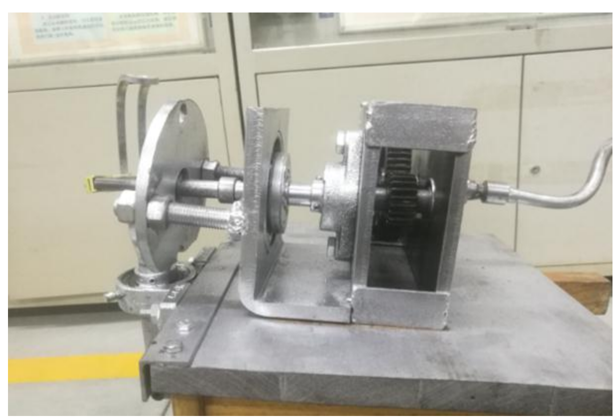

Figure 12. Auxiliary device product drawing

V. CONCLUSION

In this paper, the selection and treatment of wood, the theoretical analysis of fire conditions and the design and manufacture of simple auxiliary device is studied, and the fire of drilling wood is raised to the height of scientific research. And drilling wood to make fire and tribology are closely linked together. After the experiment, the designed simple device can meet the requirements, and the fire can be produced in the expected time.

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