Prototype and Evaluation of Cutting Force Testing Machine for Hand Work Tools

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Abstract. The goal of our study is to find a cutting edge angle with high cutting ability and durability for hand work tool. For this purpose, we developed a device to measure the cutting force of the hand work tool and evaluate its performance. At first, we examined the fixed method to correctly measure cutting force. Next, we perform many cutting experiments and evaluated the performance of the prototype force testing machine. After the validity of the testing machine has been proved, the relation between the cutting edge angle and the cutting force was examined for the three manufacturer.

1. Introduction

Pliers and Nipper are widely used as the hand work tool. In recent years even if various processes are automated, the blade sharpening process is manual operation. In case of the blade sharpening process, it focuses that the no gaps when aligning blades. That is, there is only an approximate standard for the cutting edge angle. It seems that this process causes variations in the product quality.

In this study, our goal is to find a cutting edge angle with high cutting ability and durability. For this purpose, we need a device to evaluate the cutting force, but there is no the dedicated device for now. In this study we manufacture a prototype of cutting force testing machine for the hand tool and evaluate the cutting force when cutting the copper wire.

2. Prototype cutting force testing machine

In order to clarify the relationship between the cutting edge angle and cutting force, an apparatus for evaluating cutting force is required. There is no device to measure the cutting force of a work tool such as Nipper, it seems to measure it by attaching a special jig to the tensile testing machine. Therefore, we designed and manufactured a cutting force test machine at first.

Figure 1. Prototype cutting force testing machine (Photo).
2.1 Device configuration.

The cutting force test machine manufactured is shown in figure 1. The right side of the figure is the fixed side, it is comprised of base, load cell and fixture. The load cell (TCLZ-10KNA, rated capacity: 10 kN, rated output: 4000×10^{-6}) and the dynamic strain amplifier (DC-97A, rated output: 1~10 V, sensitivity: 50~10000 μS) made by TML. Fixtures are replaceable and can be selected from the surfaces, line and point fixation. The left side of the figure is the load imparting side, it is comprised of base, toggle clamp (MC07-3, stroke: 30 mm) made by MISUMI and tip tool.

The relationship between the force applied rod and the force acting on edge is shown in the equation (1). Here, $F_1$ is the force acting on edge, $F_2$ is the force applied rod, $a$ is the distance from the pivot point to a wire, and $b$ is the distance from the pivot point to a rod.

\[ F_1 = F_2 \left( \frac{b}{a} \right) \quad (1) \]

Figure 3(a) shows an example of the cutting force measured when the copper wire is cut in actual, where the experimental condition is $a = 20$ mm, $b = 100$ mm. The part where measurement value goes up and down largely, it is considered that the copper wire was cut and caused by hitting the left and right blades. Therefore, we removed this part because it has nothing to do with the sharpness of the blade. Because the measured value contains noise, we smooth it using a moving average filter. The waveform through this filter are shown in figure 3(b). Assuming that the maximum value after these numerical processes is $F_{max}$, the force actually acting on the rod can be obtained by the equation (2). Here, $V_i$ is the input voltage, $R_o$ is the rated output voltage.

\[ F_2 = V_i \left( \frac{F_{max}}{R_o} \right) \quad (2) \]
Table 1. Shape of fixture for hand work tool.

| Surface | Line | Point |
|---------|------|-------|
| ![Surface fixture](image) | ![Line fixture](image) | ![Point fixture](image) |

Figure 4. Cutting force with different fixed method.

Table 2. Evaluation of cutting force with different fixed method.

| Fixture | Surface | Line | Point |
|---------|---------|------|-------|
| Average force [kN] | 0.549 | 0.502 | 0.506 |
| Standard deviation | 0.00621 | 0.0184 | 0.00418 |

2.2. Comparison of Fixed Method.
To decide fixed method of the work tool when measuring cutting force, three kinds of fixture were designed and compared cutting forces. In this experiment, using the plastic nipper (classified in slant edge cutting nippers), the cutting force was measured for three kinds of fixture. The shape of fixture for hand work tool are summarized in table 1.

From the results shown in figure 4 and table 2 showing the cutting force by different fixed methods and its evaluation, it was found that the cutting force of surface fixed is larger than the other fixed method, and the dispersion of the cutting force due to the fixture is small. The reason that the cutting force of the surface fixed is large, it is considered to be related to the contact area between the nipper and the fixture. In this study, we decided to use surface fixation that is stable and has small variations.

2.3. Evaluation of testing machine (change in cutting place).
As one of the evaluation items of the device, it was verified whether the cutting force varies depending on the cutting position of the wire. Table 3 shows the result of average cutting force and standard deviation. There are few differences between average force and standard deviation. It is considered that the value of cutting force is not significantly affected by the cutting position.
2.4. Evaluation of testing machine (repeatability).

To decide the number of measurement, the tool was repositioned after one set (10 measurements) and these were repeated ten times (total 100 measurements). The experimental conditions are as follows: the distance from the pivot point to the wire $a = 17$ mm and to the rod $b = 80$ mm, the fixed method is the surface fixation, and the cutting material is copper wire.

Table 4 shows the result of comparing the average cutting force of 10 sets. As described above, one set is the average value of the 10 measurements, for example, in the fourth set, the average value of 10 measurements is 0.961 kN. The average cutting force of the ten sets was 0.950 kN. The difference between the average value of each set and total is at most 2.3%, and the error rate is small. Therefore, the number of measurements is shown to be valid with at least one set (10 measurements).

2.5. Cutting force per manufacturer

In order to examine the relationship between the cutting edge angle and the cutting force, we make the cutting experiment using the nipper of three manufacturer, T, M and F company. In experiment, after cutting the wire material 20 times, measured the cutting edge angle with a microscope. The measured cutting force of each manufacturer show in figure 5. In this figure, although the measured values have dispersion, it is clear that there is a difference in cutting force for nipper of each manufacturer. Figure 6 is a schematic view of the cutting edge angle, and table 5 shows the cutting edge angle and average load of each company. The nipper with small edge angle has a small average cutting force, in case of large edge angle has a large average force. As a matter of course, the cutting ability can be improved by decreasing the edge angle.
Table 5. Comparison of cutting force and edge angle.

|            | T  | F  | M  |
|------------|----|----|----|
| Left edge  | 45.0 | 49.1 | 49.1 |
| Right edge | 39.5 | 45.0 | 44.8 |
| Average force [N] | 546  | 605  | 578  |

3. Summary
In this study, we developed and manufactured device to measure the cutting force. In order to improve the repeatability of the measurement, we first examined the fixed method of the hand work tool and showed that the surface fixation can be measured stably. In the number of measurements, it is shown to be valid with at least one set (10 measurements) as a result of 100 measurements. Moreover, in actual cutting test using the nipper of three manufacturer, the relationship between the edge angle and cutting force was clarified.

Reference
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