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The usability and ergonomics of axes

Minna Päivinen*, Tanja Heinimaa

Center for Safety Management and Engineering, Tampere University of Technology, PO Box 541, FIN-33101 Tampere, Finland

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ABSTRACT

This study evaluated the ergonomics and usability of axes. Several methods were used, namely measurement of impact velocity, the determination of kinetic energy, splitting performance tests, durability tests of blades and handles, and user trials. The mean velocity used in the striking was 9.6 m/s (8.9–10.3 m/s, SD 1.5). In the durability tests, the blades withstood the test reasonably well. In the bending tests, there were differences in the durability of the handles, which related to their material. A wide variation in the durability of the axe handles was also observed. User trials were conducted to evaluate the various features of the axes.

1. Introduction

Good ergonomics is seen as a central principle of successful design. Customers have come to expect and demand products that are easy to use. To succeed, a product or system must provide satisfactory interaction with its user or customer at both a functional and cultural level (Popovic, 1997). Quantification of ergonomics and usability takes these issues into a concrete domain that can be understood by others involved in the product creation process (Green and Jordan, 1999).

In today's fast changing and intensely competitive marketplace with rapid technological evolution, manufacturing companies are forced to design better performing and less expensive consumer products at a rapid pace (Krishnan et al., 1995, 1997; Kuijt-Evers et al., 2004; Popovic, 1997; Sabbaghian and Eppinger, 1998; Willén, 1997).

By improving the ergonomics and usability of hand tools, work efficiency, productivity and quality, as well as user comfort and safety can be improved (Buchholz et al., 1992; Kadefors et al., 1993; Kardborn, 1998; Kilbom et al., 1993; Kuijt-Evers et al., 2004, 2007; Meagher, 1987; Sperling et al., 1993; Tudor, 1996; You et al., 2005). Ergonomically well-designed hand tools used in work situations with balanced work content reduce the risk of occupational injuries of the hand, wrist and forearm (Sperling et al., 1993).

It has been demonstrated that by improving the ergonomic quality of hand tools as well as comfort, it is possible to increase work productivity (Kilbom et al., 1993; Kuijt-Evers et al., 2007). This is also important from the viewpoint of workers' health because they normally use tools with the highest productivity, even at the cost of a higher degree of strain and fatigue (Kadefors et al., 1993; Kilbom et al., 1993).

The context in which axes are used has shifted from professional to leisure time settings. Nonetheless, hand axes still play an essential role in agriculture and forestry, despite high-tech forest technology and the increasingly mechanised forest industry. By improving the usability of axes, it should be possible to reduce work load and increase productivity. Furthermore, ergonomic axes may decrease the number of accidents and cumulative trauma disorders.

1.1. Study aims

The aims of this study were to investigate the ergonomics and usability of different axes and to identify design features requiring ergonomics and usability modifications. The purpose was to collect both objective and subjective data on axes.

2. Materials and methods

The study began by testing the effects of different blade coatings on the force demands when cutting wood. This part of the study has been reported earlier and thus will not be discussed further in this paper (Päivinen and Heinimaa, 2003). This study consisted of the following methods:

* Corresponding author. Tel.: +358 3 3115 2507; fax: +358 3 3115 2671.
E-mail address: minna.paivinen@tut.fi (M. Päivinen).

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1. Measurement of striking speed and determination of kinetic energy.
2. Performance tests.
3. Durability tests.
a. Blades.
b. Handle: bending and shock resistance.
4. User trials.

In durability tests a combination of standard procedures (ASME B107.55M-1998; BS 2945:1995) was used. Standards concerning other issues of this study were not available.

2.1. The tested axes

Seven different axes representing the models commercially available in the Nordic countries and Central Europe were selected (Table 1, Fig. 1). All axe models were intended for use when splitting wood. They represent rather big axes, which are used mainly when making firewood. Smaller axes, used for making camp fires or doing woodwork, were not included in this study. The axes were in the condition in which the customer buys them. The mass of the axes was 1770–2719 g.

2.2. Impact velocity test and the determination of kinetic energy

In order to determine the kinetic energy of axes, the impact velocities were tested. The test was carried out under laboratory conditions using a "velometer". The system measures the time taken for the axe to travel vertically between two parallel laser beams arranged above and below each other. As the time and distance between the two beams is known, the velocity of the axe can thus be calculated. The axes were struck into a thick paper bale (thickness of approximately 30 cm) instead of wood, in order to prevent splinters which could have damaged the sensitive testing equipment. Participants were instructed to use the axe as if they were splitting a block of fresh pine wood 25–30 cm in height and 15–20 cm in diameter.

In this part of the study there were five participants (two males and three females). The participants were on average 27 years (24–33 years), their mean height was 173 cm (163–188 cm) and their mean weight was 66 kg (57–90 kg). Their gripping strength was measured (Jamar Hand Dynamometer) before the tests and averaged 47 kg (40–69 kg). The participants were familiar with the task and had some experience of using axes to make firewood. Each participant performed five strikes with each axe. There was a 5-min rest period between each strike.

The kinetic energy (E_k) in a striking situation was determined according to the mass (m) of the axes and the results of the striking velocity (v) measurements (Eq. (1)):

$$E_k = \frac{1}{2} m_1 v_1^2 \quad (1)$$

where m_1 = mass of the axe and v_1 = striking velocity.

Table 1
The studied axes ($n = 7$) and their mass (g), total length (cm) and handle length (cm).

Axe	Total mass (g)	Total length (cm)	Handle length (cm)
A	2546	72.0	65.5
B	2719	75.0	69.0
C	2301	69.5	63.5
D	1848	74.5	66.5
E	1431	60.0	53.0
F	1770	66.0	58.5
G	1437	65.0	58.5

2.3. Splitting performance test

One objective was to compare the wood splitting effectiveness of the axes, for which a special testing system was developed and constructed. In the testing system the axe was fastened to a specially designed frame. The frame ran between a pair of vertical rails in which it could be elevated and lowered (Fig. 2). As the frame was elevated it could then be released by a signal from a control unit. The height of elevation was precisely determined.

The dropping height was calculated to represent the equivalent kinetic energy of real work with axes, thus the potential energy (E_p) should equal the kinetic energy (E_k) (Eq. (2)):

$$E_k = E_p = mgh = (m_1 + m_2)gh \quad (2)$$

$$h = E_p/[(m_1 + m_2)g]$$

where m_1 = mass of the axe, m_2 = mass of the frame and $g = 9.81\ m/s^2$.

The height of the drop was defined according to the values derived from the impact velocity tests. According to the calculation of the kinetic energy, the height of the drop was 4.7 m with an axe of medium weight. As it was not possible to achieve this height under laboratory conditions, the dropping height had to be compensated by increasing the weight of the frame. Though this increase compensated the kinetic energy, it resulted in a decrease in impact velocity. For an axe of average weight the dropping height was set at 0.93 m, resulting in an impact velocity of 4.3 m/s.

In the tests the axes were dropped from a height of 0.93 m onto a stack of eight finely sawn wooden boards of uniform quality (18 mm × 120 mm × 300 mm). The test was then repeated 10 times with each of the seven axes. The results are based on the number of boards that split under the axes.

2.4. Durability tests

The safety of the axes also depends on their durability. Separate durability tests were performed on the axe handles and blades, which were then examined. The aim was to determine how well the handles withstood a situation where the axe blade misses the target and the impact force is directed to axe handle. In the durability tests for the blades, the aim was to ascertain the effects of hitting an unexpected object such as a nail.

The same equipment was used in the durability tests and splitting performance tests (Fig. 2). The axes were again dropped from a height of 0.93 cm to simulate the energy of a typical axe stroke. The same axe models were used as in the other tests. Now the axes were dropped three times each onto typical construction ribbed steel with the diameter of 12 mm (Fig. 3). The ribbed steel produces a higher load for the blades than, say nails, since it is thicker and harder. The results are based on observations of how the blades withstood the test.

The durability of the handles was tested in order to examine how durable the handles are when they are bent or how shock resistant they prove to be. Two standards were used as guidelines to specify and design the bending test procedure (ASME B107.55M-1998; BS 2945:1995). As the standards could not be directly applied in the current situation, and no ISO standards for this issue exist, their procedures were combined. The bending test was performed by securing the axe blade in a bench vice and then applying a constantly increasing force directed at a distance of 76 mm from the end of the handle. The force was then monitored through a scale attached to the end of the handle and the test continued until the handle broke. One axe per model was tested.

The shock resistance tests were performed using specially designed equipment. The axe was fastened to the end of the handle