Investigation of knife quality by using forging and flame hardening methods

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Abstract. The research was conducted to investigate the quality of knives the material and the forging process against wear resistance. The forged material is AISI 1050 steel, AISI 4340 steel, AISI L-6 steel, and JIS SUP 9 steel. The manufacturing of the knives were done by heating the material to a temperature ranging from 900-950°C then forged repeatedly manually until the temperature drop in between 650-675°C. Heating and forging are carried out several cycles to form a knife. Hardening was done by heating the knives to reach austenite temperature by flame hardening method, then quenching using water cooling media. Research of wear resistance was done on the sharp side by using an actuator tribometer pin-on-plate. The results showed that wear and tear were influenced by the material and the treatment. Flame hardening process can be reduced the wear rate, the wear rate found on AISI 1050 steel knives is 5.439 x 10^-4 mm³/Nm after being forged, while the lowest wear rate was found on AISI L-6 steel knife which ware 2.44 x 10^-5 mm³/Nm after flame hardening. The flame hardening process can reduce the wear rate, highest wear rate found on AISI 1050 steel knives ware 5.439 x 10^-4 mm³/Nm after being forged, while the lowest wear rate was found on AISI L-6 steel knife which is 2.44 x 10^-5 mm³/Nm after flame hardening. Therefore, it can be conclude that traditional knife quality especially the wear resistance can be improved by optimizing the heat treatment schedule.

1. Introduction
Cutting components are often found in agricultural machinerys and food processing. The ability of the cutting component was determined by the quality of the material and the manufacturing method used. The manufacturing process of the knife from steel bar, ingot, or plate is typically done by forging [1]. The knife making community knows two methods of making quality knives namely the Damascus method and pattern welding [2-3]. Both methods are the same as the methods used by traditional blacksmiths but it is differed in terms of the material used. traditional blacksmiths produce knives with limited metallurgy knowledge, so the knives were produced is low quality. In theory, the quality of traditional blacksmiths blades can be improved by selecting materials, manufacturing processes, heating treatment, and proper finishing

Damascus steel elements indicated that there are 1.60% C, 0.56% Mn, 0.17%P, 0.02% S, 0.048% Si, 0.012%Ni, 0.048% Cu, 0.01% V dan 0.002%Ti [4]. Damascus steel included in high carbon steel (ultra-high carbon (UHC)) with the chemical composition including hyper-eutectoid consisting of pearlite (lamellar cementite and ferrite). On the knife surface cementite sheets are not arranged in parallel but
are corrugated, this matter was influenced by the forging process which is not uniformly but in the form of a damask pattern.

Steel AISI 1086, damascus steel, AISI 52100 steel and AEB-L steel also have different sharpness levels after forging, quenching and tempering treatment [5]. Steel AISI 52100 with a hardness of 61 HRC has a better sharpness than AISI 1086. However, the hardness value of 41 HRC with fine pearlite matrix or quenching results and tempering damascus steel has a slightly better side sharp edge than AISI 52100 steel, AISI 1086 steel, and AEB-L steel.

Theoretically knife’s quality which produced by blacksmith can be improved with right material choice, good manufacturing process, and perfect finishing process. In this work, we study the traditional forging method done by a local blacksmith to make a knife from the various of the steel. Our goal of this research is to develop the process parameter to control the wear resistance of the knife.

2. Research method

2.1 Knife Making Method

Workpieces that have been cut then heated by using a blacksmith furnace with charcoal fuel. The time to reach the forging temperature depends on the material and dimensions used. The maximum temperature limit in the forging process is 50°C below the liquidus line the phase diagram Table 1 below shows the temperature and the heating temperature of each knife materials

| Materials     | Preheating   | Heating in the forging process |
|---------------|--------------|--------------------------------|
|               | Temperature  | Time (second) | Temperature | Time (second) |
|               | (°C)         |              | (°C)        |              |
| JIS SUP 9     | 34-850       | 195          | 390-850     | 56           |
| AISI 1050     | 34-850       | 210          | 400-859     | 58           |
| AISI L-6      | 34-957       | 265          | 625-957     | 79           |
| AISI 4340     | 34-839       | 306          | 531-839     | 61           |

The material that has been heated using a blacksmith furnace then placed on the top of the anvil by using a clamp as a handle, then forged repeatedly using a hammer. In one heating, forging was carried out between 32-39 times per 10 cm with forging time ranging between 28-35 seconds. The forging cycle was carried out several times to forming the knife with forging temperature as shown in Table 2.

| Materials     | Forging temperature (°C) | Forging time (second) | Max forging amount (Time) |
|---------------|--------------------------|-----------------------|-------------------------|
| JIS SUP 9     | 810-390                  | 35                    | 39                      |
| AISI 1050     | 819-400                  | 35                    | 38                      |
| AISI L-6      | 950-625                  | 28                    | 32                      |
| AISI 4340     | 830-531                  | 34                    | 38                      |

2.2 Flame Hardening method

Manual flame hardening was done by heating the knife surface reach a temperature of 850°C. Heating was done by using a mixture of oxygen and liquid petroleum gas (LPG), Then the knife is quenched using cooling media form of water.
2.3 Wear resistance test
Before measuring the wear resistance, the knives were cut with dimensions of 10 mm, long and thickness adjusted to the dimensions of the knife. Then the sharp side surface was smoothed using a grinding tool machine as shown in Figure 1a. Next, weigh the mass of the specimen before and have tested the wear resistance in order to find out the lost mass of each knife specimen. Then weigh the mass of the specimen before and after testing the wear resistance in order to find out the lost mass of each knife specimen.

![Wear resistant test specimen](image1.png) ![Testing process is wear resistant](image2.png)

Figure 1 Testing is wear resistant

Wear resistance testing was carried out using a pin-on-plate tribometer actuator as shown in Figure 1b. In the test equipment, a load of 1290 g was given, then swiping the sharp side of the knife specimen on the plate that agitates back and forth for 25 minutes with a swipe plate speed of 0.4 m/s. Testing every condition was carried out two measurements then taken on average. The weight difference before and after the test is the wear data from the knife specimen. Specific wear rate is calculated using the following equation[6].

\[
K = \frac{\Delta V}{F \cdot L}
\]

Where \( K \) is the specific wear rate (mm³/Nm), \( \Delta V \) is the volume changes (mm³), \( F \) is the force applied (N), and \( L \) is the distance sliding (m).

3. Experiment Results
Knives after forged are shaped as shown in Figure 2. The results of visual observation showed that on each knife did not defect occur.

![Steel knife 4340 manual forging results](image3.png)

Figure 2 Steel knife 4340 manual forging results

Friction of the knife with other objects when cutting will cause a loss of sharp edges. In the end it causes the knife to wear out so that it cannot cut perfectly. Wear resistance defined as the weight of the knife specimen reduced after sharp side friction with hard objects. From the test results obtained the specific wear rate value on the knife material after being forged as shown in Figure 3.
From Figure 3, it can be observed that the forging process, the highest wear resistance occurs in AISI 1050 steel knife in the amount of $5.439 \times 10^{-4}$ mm$^3$/Nm. The lowest wear resistance of steel knife AISI L-6 is $1.059 \times 10^{-4}$ mm$^3$/Nm. While the wear resistance of AISI 4340 steel blade is $1.678 \times 10^{-4}$ mm$^3$/Nm lower than the wear resistance that occurs in steel knife JIS SUP 9 is $3.575 \times 10^{-4}$ mm$^3$/Nm. After the hardening is carried out, there is an increase in wear resistance in each knife as shown in Figure 4.

On steel knife of AISI 1050 of wear resistance is $5.66 \times 10^{-5}$ mm$^3$/Nm higher than AISI 4340 steel knife, AISI L-6 and JIS SUP 9. The lowest wear resistance occurs in steel knife AISI L-6 is $2.44 \times 10^{-5}$ mm$^3$/Nm. From the type of material, it can be observed that the highest wear resistance occurs in AISI 1050 steel knife and the lowest is in AISI L-6 steel knife as shown in Figure 3-4, this is also due to differences in levels of violence [6-7]. The JIS SUP 9 knife material has the highest hardness value after being hardened. In addition, Cr levels of the material can be also kept wear resistance levels. Steel AISI L-6 has a Cr content of 1.13% while AISI 1050 has a Cr content of 0.0262%. Increased wear resistance is also caused by microstructure in the material [8-10].
4. Conclusion
The quality of the knife was affected by the type of material and the flame hardening process. The knife of the forging process has a higher wear rate compared to the knife of the flame hardening process. The highest wear rate obtained on AISI 1050 steel knife is $5.439 \times 10^{-4} \text{ mm}^3/\text{Nm}$ after the forging process. The lowest wear rate is $2.44 \times 10^{-5} \text{ mm}^3/\text{Nm}$ obtained on AISI L-6 steel material after the flame hardening process.

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