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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 ware done by heating the material to a temperature ranging from 900-950^{o}C then forged repeatedly manually until the temperature drop in between 650-675^{o}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. The flame hardening process can be reduced the wear rate, the wear rate found on AISI 1050 steel knives is 5.439 x 10^{-4} mm^3/Nm after being forged, while the lowest wear rate was found on AISI L-6 steel knife which ware 2.44 x10^{-5} mm^3/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} mm^3/Nm after being forged, while the lowest wear rate was found on AISI L-6 steel knife which is 2.44 x 10^{-5} mm^3/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 machineryies 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

Table 1 Temperature and heating time.

Materials	Preheating		Heating in the forging process	
	Temperature (°C)	Time (second)	Temperature (°C)	Time (second)
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.

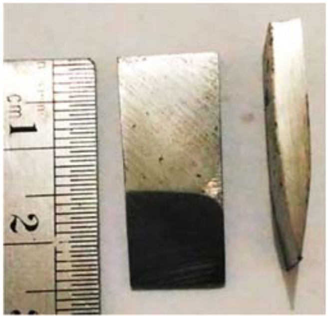
Table 2 Forging temperature and amount of forging.

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 was 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 griding 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 tested the wear resistance in order to find out the lost mass of each knife specimen.



(a) Wear resistant test specimen

(b) Testing process is wear resistant

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 was given a load of as 1290 g, 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].

$$K = \frac{\Delta V}{F \cdot L} \quad (1)$$

Where K is the Spesific wear rate (mm^3/Nm), ΔV is the volume changes (mm^3), F is the force applied (N), 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.

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 show in Figure 3.

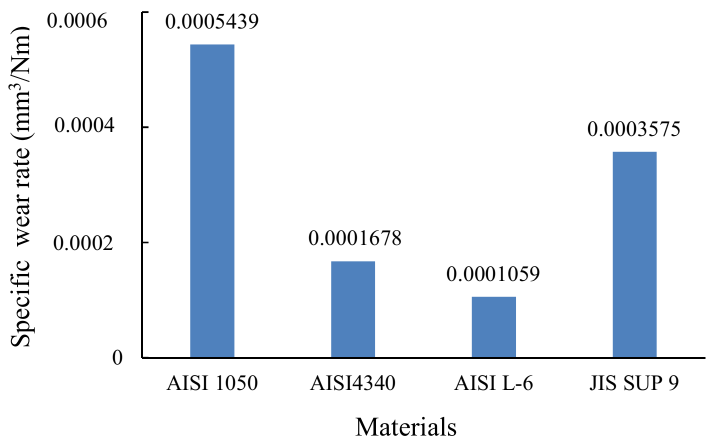


Figure 3 Graph the rate of wear resistance of the Knife after being forged

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 x 10^{-4} mm^3/Nm. the lowest wear resistance of steel knife AISI L-6 is 1.059 x 10^{-4} mm^3/Nm. While the wear resistance of AISI 4340 steel blade is 1.678 x 10^{-4} mm^3/Nm lower than the wear resistance that occurs in steel knife JIS SUP 9 is 3.575 x 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.

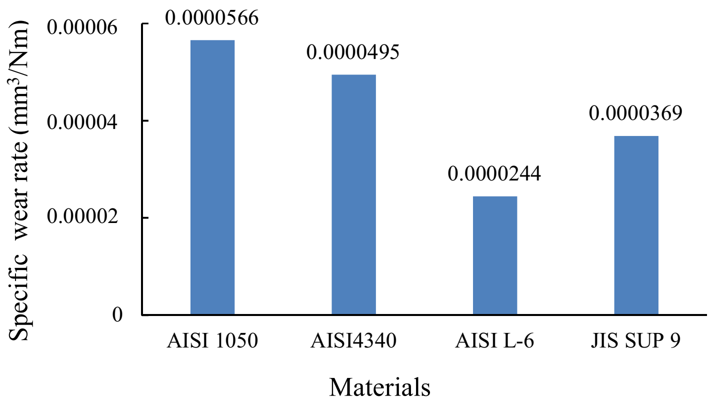


Figure 4 Graph the rate of wear resistance of the Knife after flame hardenig

On steel knife of AISI 1050 of wear resistance is 5.66 x 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 x 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].

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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 x 10^{-4} mm^3/Nm after the forging process. The lowest wear rate is 2.44 x 10^{-5} mm^3/Nm obtained on AISI L-6 steel material after the flame hardening process.

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