Experiment Design for Manufacturing Quality Kitchen Knife Materials using Carbon Steel with Hard Facing Technology and Hot Forging Process

Fransiskus Sapar, Oktovianus Dharma Rerung, Roymons Jimmy Dimu and Abdul Umar Muttaqin
Dept. of Mechanical Engineering, Kupang State Polytechnic, My Street, Kupang, Indonesia

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Abstract: Forging work is to form metal to produce a final product by providing a compressive force at a certainty loading speed. Forging at high heat will soften the material when struck with a hammer or by compressive forces. One of the forging products is a work knife in the kitchen. Production usually has corrosion resistance and wear resistance. In addition to stainless steel, knives it also made of carbon steel, leaf plate spring steel, and other heavy equipment steel waste. Manufacture of blades by engineering the addition of metal to parts with hardened welding technology. The selection of electrodes considers quality by choosing electrodes with alloy steel compositions such as Manganese (Mn), Chromium (Cr), Silicon (Si). Hard-facing data on two types of hard-facing material and leaf plate spring steel showed an increase in the hardness of these materials. Analysis of variance shows the effect of material factors and hardening factors by quenching on the hardness of the test material. In addition to hardness, the analysis results show the material's resistance to rust. The influence of the chemical composition of the alloy steel, namely chromium, causes corrosion resistance of the test material. Another interesting fact thing is the use of control variables in testing between variables. The variable used is a knife to analyze descriptively under binocular microscope observation.

1 INTRODUCTION

Forging work is a metal forming process by applying a compressive force with a certain things load rate. Forging will produce products such as hammers, chisels, knives, and others. The main principle of forging is hitting or pressing an object in a hot or cold state with molds and tools (Rathi and Jakhade, 2014). There are three type of Forging: Cold Forging, Warm Forging & Hot Forging. This manufacturing process of metal shaping can be done through Hammering, Pressing & Rolling. The General concept of forging is that the metal is deformed plastically to the desired Shape by giving a high fatigue resistance and strength (Ruban and Jayaprakash, 2020). One of the forging products is a kitchen knife. The basis of knife making is to prioritize wear resistance (Balkhaya1*, M P Anhar1, Suwarno2, 2019). Kitchen knives are plays with important to households, restaurants, hospitals, and star hotels. Kitchen knives consist of various types according to their function and quality. The price also varies from cheap to expensive knives. People, in general, use a knife with an anti-rust base material, namely stainless steel. In addition to stainless steel, it also uses friction-resistant and impact-resistant materials. Other materials have to make kitchen knives are: carbon steels, leaf plate steels, waste steel from heavy pieces of equipment, and industrial steel that is considered tough. Considering the pricess of stainless steel and its alloys is quite expensive, the researchers tried to engineer it using carbon steel. Carbon steel is commercial steel, cheap, and available in the market. Carbon steel is engineered into more special steel by adding alloying metals to the material side with hard-facing welding technology. Hardfacing welding uses special electrodes with chemical compositions of manganese (Mn), chromium (Cr), and silicon (Si). This electrode is an FN Mn (E7-UM-200Kp) welding electrode as a binder in the first layer and the second layer uses a hard FN 1000 (E-UM-60) welding electrode..

One of the interesting things about this experimental design is work with hardfacing technology that is not commonly used for the forging process but the addition of a hard alloy metal that is impact-resistant, abrasive, tough, corrosion-resistant

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(Pradeep, Ramesh and Prasad, 2010). Research is also working on hardening treatment both in the process and treatment at the final touch and other tests are carried out as a measured quality.

Heat treatment is the controlled process of heating and cooling of metal to alter their mechanical and physical properties without changing the product shape. The heat treatment process is defined as heating a metal at various temperatures, holding them for various time duration and cooling at various rates, it helps to improve the machining, formability, restore ductility after a cold working operation (Khera *et al.*, 2014).

The measure used as an experimental strength of the engineered knife material is hardening at austenite temperature of 900°C with water and diesel cooling. Carrying out hardness testing after the forging process and sharpness by observing directly the sharpening time and the selection of the whetstone used. The whetstone used is commonly used in the market ranging from coarse to grit 400 (coarse), medium grit 1000, normal sharpness with 1200-1500 grit, and fine grit ranging from 3000-10,000 grit. Binocular microscopic photos were taken on the sharp blade area with 500x magnification and 10x zoom to see the shape and morphology of the sharp blade. The main objective of the research is to produce advanced quality kitchen knife materials by engineering hardening, cooling media, material hardness testing (Hardness Rockwell, HRC), and cutting tests.

2 METHODOLOGY

2.1 Research Stages

Figure 1, Starting the research by compiling a flow chart from the beginning to reaching the final goal. The beginning of already shows the preparation of materials with the concept of true experimental research and action experiments. The blade material is carbon steel with hard-facing welding and leaf plate steel as the reference material. Leaf plate steel is special alloy steel whose use for automobile springs is called leaf plate springs. In general, this type of waste iron is suitable material for making knives, even though the price is quite expensive.

Starting from research on how to prepare the main ingredients for making kitchen work knives by designing and manufacturing carbon steel coated with metal alloys, especially those rich in Manganese (Mn), Chromium (Cr), and Silicon (Si). It further combines the function of manganese as a hard and friction-resistant metal with impact-resistant and rust-resistant Chromium. Corrosion resistant chromium in composition equal to or greater than 16%. While the element of silicon is needed to increase the strength and hardness of steel. This element can stabilize the carbide formed by the addition of other alloys. To realize the steel design, welding uses hardfacing technology, which forms a new metal layer coated with a hard, strong, friction-resistant, impact-resistant, and rust-resistant base metal surface.

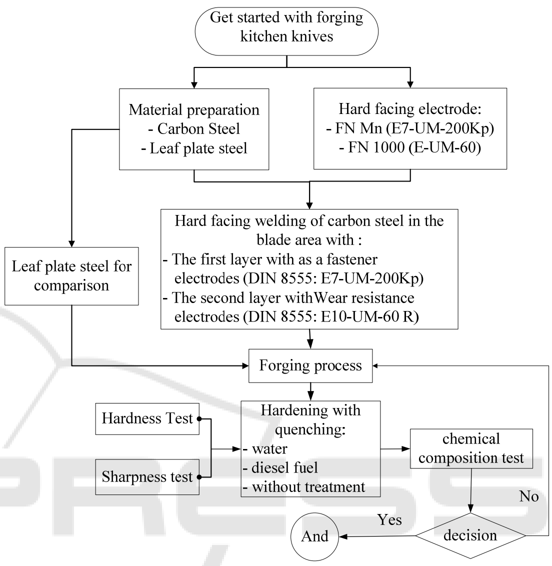

Figure 1: Research flow chart.

Hard facing must be a composite, with a base material with high hardness and a coarse microstructure showing strength (Venkatesh, Sriker and Prabhakar, 2015). The method used is SMAW welding method. The first layer is a base layer that functions as a binder using DIN 8555: E7-UM-200Kp electrodes which are rich in Mn and Si. Then a second layer of welding was carried out with DIN 8555: E10-UM-60 R electrodes with 33% chromium composition. After the main material is prepared, then hot forging, straightening and leveling of the workpiece surface are carried out. Carry out work carefully and regularly, especially forging, grinding, and sanding. The basic process is carried out in which the workpiece is shaped by compressive forces applied through various molds and tools. (Engineering, no date) The sequence of work is an important part of forming a rough knife according to the desired design. In this process, usually simple billets are subjected to plastic deformation between dies during one or more operations (Design, 1995).

Before finishing touch, smooth the part of the knife to be tested for hardness so that when the knife is finished smoothing it does not interfere with the hardening process with cooling water and diesel fuel, which are considered as fast quenching media to get the best hardness results.

Figure 2: Cause-and-effect relationship diagram design.

After the finishing knife has been formed, then do a sharpness test by sharpening it according to the grit of the grinding stone on the market. One thing that is important is how the quality of the steel is in the knife, the quality will be seen at the sharp edge of the failure or not.(Salomon, Kosasih and Angkasa, 2017). The grit on the market ranges from coarse, medium-fine, to very fine. The next step is a binocular microscope with a photo magnification of 500 times and a magnification of 10 times. The explanation of the whole research requires a tool, namely a cause-and-effect diagram in the form of a road map. Figure 2. A cause-and-effect diagram also known as an Ishikawa diagram or fishbone diagram. The aim is to identify and categorize the causes that produce the quality problems that make them souseful instrument in the risk identification stage (Masoud Hekmatpanah, 2011).

2.2 Research Design

The research location was carried out at the Kupang State Polytechnic Material Testing Laboratory. Forging work by cooperating with a small industry in the village of Namosain. The research method uses a true experimental design and action method. True experimental design research is a type of research that explains the relationship between the observations of the treatment group and the control group. We then discuss three key categories of experimental design: lab-experiments, quasi-experiments, and factorial design experiments(Levy and Ellis, 2011).

Next, explain these comparisons closely. Material cutting, design, and manufacture are hands-on in the laboratory while the forging process is in collaboration with blacksmiths at the Namosin workshop. Scientific analysis by conducting tests, among others, hardening testing, hardness testing, testing with microscopic photos and sharpening knife materials.

2.3 Research Variable

Testing the relationship between variables usually uses a causal relationship in a sufficient number of populations. This data uses a tool with ANOVA analysis. This will be achieved by a statistical analysis of experimental data using the one-way ANOVA F-test. The approach of ANOVA test is based on the breakdown of the total variation within an experiment into variations due to each main factor, interacting factors and residual (experimental) error (Joseph and Alo, 2014). The next discussion is the independent variables on the dependent variable. Carbon steel that has received hard-facing welding is then heat-treated at a temperature of 900 °C with a holding time of 60 minutes. The next step is to dip in two media, namely water, and diesel. The dependent variable is the hardness value on the Rockwell Hardness B (HRB) or Rockwell C (HRC) Hardness scale. The next step is to control the relationship between these variables. The control variable is the sharpness of the knife by describing it in the form of microscopic photos with 1000x magnification using a binocular microscope. The hope is to produce quality knife material data and can be used as an alternative to making kitchen knives.

3 DISCUSSION

The previous discussion mentioned that the uniqueness of the research causes the relationship between variables not only to explain in the form of between variables. The research also explains in the form of descriptions and narrative descriptions. The relationship between these variables is the material for making knives, both untreated and heat-treated for hardness. This happens to explain the relationship between variables and support it with images such as knife sharpness images. The explanation in the introduction to the discussion above is to better understand the next series of research.

3.1 Experiment Execution

Experimental planning describes a test that observes and takes data directly. The results of the hardness test are presented in table 1 and table 2. In table 1 shows the data on the material facing forward, while table 2 is the material that uses leaf plate steel.

Table 1: Material hardness test results with hard facing welding.

Hard Facing Material (Hf)	No	Without treatment(Q1)	Hardening 900 °C Quenching : Water (Q2)	Hardening 900 °C Quenching : Solar fuel (Q3)
Hardness	1	46,33	60,11	58,33
	2	49,86	59,60	51,77
	3	45,11	62,35	60,12
	4	47,99	59,23	56,25
	5	51,40	63,10	52,11
	6	47,88	61,11	53,44
	7	45,12	62,12	56,77
	8	44,89	59,44	51,85
	9	47,12	58,77	50,88
	10	50,77	60,55	51,35

The two tables show the results of hardness tests that relate the treatment of each material to heat treatment at 900 C. Cooling is done after a holding time of 60 minutes in a furnace using water and diesel. Given that the two test materials are in the same test form, the two data tables are combined to form a factorial causal relationship. the results of the hardness test into two levels of material and three factors to form 2x3.

Table 2: Results of hardness test with leaf plate steel material.

Leaf Plate (Lp) Steel	No	Without treatment(Q1)	Hardening 900 °C Quenching : Water (Q2)	Hardening 900 °C *Quenching :* Solar fuel (Q3)
Hardness	1	44,40	55,45	55,45
	2	46,76	49,77	49,77
	3	45,67	54,30	54,30
	4	44,99	52,89	52,89
	5	40,56	53,80	53,80
	6	47,10	51,55	51,55
	7	46,76	48,27	48,27
	8	42,10	53,11	53,11
	9	43,66	50,44	50,44
	10	45,11	49,89	49,89

Scientific explanations, both processing relationships between variables and in the form of image descriptions as shown in the ANOVA results.

The data table from the calculation of ANOVA and coefficients shows that the variables that have a significant effect are hardening with water cooling (Q2) and then solar cooling (Q3). The variable that also influences is the type of material itself, namely hard facing (Hf) and Leaf Plate Steel (Lp) materials. Interactions between factors also influence even on a small scale. Overall, the appearance of the hardness data table shows that the original material and the hardening treatment have a hard material above 45 HRC. The HRC scale is a form of hardness testing using a sharp conical indenter for hard materials.

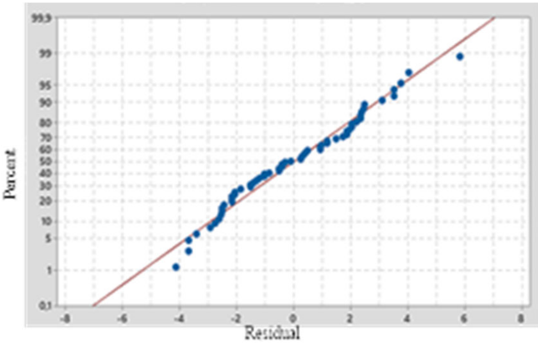

Figure 3: Normal curve of two hardness test data.

Table 3: Analysis of variance.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Material	1,00	43,10	43,10	7,59	0,01
Hardening	2,00	843,97	421,99	74,30	-
Material*Heat Treatment	2,00	123,02	61,51	10,83	-
Error	54,00	306,69	5,68		
Total	59,00	1.824,86			

Table 4: Coefficients.

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	47,647	0,754	63,22	0	
Material					
Lp	-2,94	1,07	-2,75	0,008	3
Hardening					
Q2	12,99	1,07	12,19	0	2,67
Q3	6,64	1,07	6,23	0	2,67
Material *Hardening					
Lp Q2	-5,75	1,51	-3,82	0	3,33
Lp Q3	0,6	1,51	0,4	0,694	3,33

Furthermore, to prove that using the type of material is quite tough and the type of electrode is hard facing, let's pay attention to the following table of chemical composition.

Table 5: Chemical composition of materials and Electrodes.

No.	Materials	Spesification	C	P	S	Mn	Cr	Si	Mo
1	FN Mn electrode	E7-UM-200 K	1,00	0,02	0,02	12,00	0,40	0,60	0,00
2	FN 1000 electrode	E10-Um-60 R	4,30	0,02	0,02	0,40	33,00		
3	Carbon Steel Plate	ST 37	0,30	0,02	0,02			0,40	
4	Leaf Plate Spring Steel	Suzuki LJ410	0,60	0,02	0,04	1,20	0,25	0,21	0,88

Table 5 informs the types of electrodes and materials used in the study. The hard facing electrode type uses two types of electrodes with specifications E7-UM-200Kp on the first layer and the second layer with E10_Um-60 R. The basic material uses carbon steel with a minimum tensile strength of 370 N/mm while the comparison material uses Leaf plate spring steel. The chemical composition of the E7-Um-200 Kp type electrode contains a lot of Manganese (Mn) which functions to bind and strengthen carbon steel materials. In the second layer using hard facing electrodes containing chromium (Cr) as much as 33%. Chromium functions to make the base material tough, hard, friction-resistant, and the layer soft. Hard-facing electrode hardness above 45 HRC indicates a material that produces a special 33% Cr steel alloy that is also corrosion-resistant. The explanation has described the type of material for making kitchen knives with special materials.

3.2 Blade Sharpness

The explanation of sharpness measure is still a matter of debate and eventually becomes a consideration in two main categories in the definition of what was sharp. Some have tried to define it as the force required for the substrate. Other researchers introduced the idea that points are best measured by measuring the radius and angle of the cutting edge at edge under a microscope (Mulder and Scott, 2016). Until now, there is no standard definition of measurement or basis for measuring sharpness. The tip towards the radius was the sharp part and, the ratings fall into two main categories in their measurement definition. The judgment is about what sharpness is. Some have tried to define it as the force required for the substrate. Other researchers introduced the idea that the best point in measurement is to measure the radius and angle of the cutting edge at edge under a microscope. Multiple points on the tip radius require measurements to make accurate characterizations. (Janusz, 2016). To date, there is no standard definition, measure, or protocol for measuring knife sharpness. In response to the above, this study will analyze sharpness level with the concept of one of the theories that have been put forward, namely describing the morphology of knife sharpness descriptively under a binocular microscope. The results showed that each knife as shown in Figure 4 and Figure 5. Figure 4 shows the part towards the corner radius of the knife tip showing a very rough with a hard surface and shown a brittle sharpness.

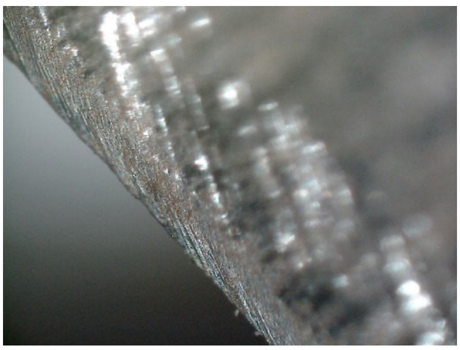

Figure 4: Water quenching blade under a binocular microscope.

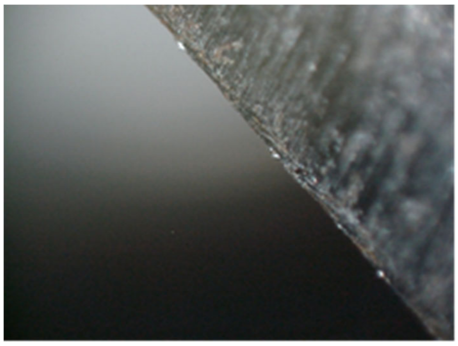

Figure 5: Diesel fuel quenching blade under a binocular microscope.

Figure 6: Leaf plate steel as a comparison material.

The blade is in the process of heat treatment by water cooling. Figure 5, The blade that received diesel fuel quenching shows a rough but slightly smoother surface than the first blade above. Blade fingers with even strokes and easier to sharpen the two-blade received hard-facing treatment but differed in the use of quenching. The third knife in Figure 6 is a comparison knife with leaf plate steel material. Leaf plate steel is alloy steel on leaf plate springs, visible part towards the spokes with a flat surface, and the blade has a feel with a diesel cooled second blade. If we compare the three pictures, it will be seeing that the first knife looks rougher and toughers by comparing it with the second knife and the third knife.

4 CONCLUSIONS

There are many interesting things from the results of the discussion that show several important points as conclusions, namely:

- The factors that affect the hardness are the type and specification of the hard-facing electrode, while the increase in hardness in the hardening test is the cooling factor with water quenching and diesel quenching. The interaction factor between the material and the hardening treatment also affects the hardnes on a small scale.How is the hardness of each knife that has received hard facing treatment compared to the leaf plate spring steel material.

- Engineered knives that use hard facing welding materials when compared with leaf steel spring plate materials have several advantages, namely resistance of corrosion, tougher, tougher and smoother blade material surface.
- Descriptive explanation of blade boundaries using the radius method by observing under a binocular microscope explains that the use of cooling with water shows a rougher surface than the material towards the radius with diesel fuel cooling. The morphology of quenching with water looks rougher and hardened, indicating a very sharp knife. If you compare the two blades with a leaf plate steel material, the similarity is a knife with diesel fuel quenching. The surface is slightly smoother and even.

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APPENDIX

WORKSHEET 5

General Linear Model: Hardness (HRC)_2 versus Material_2; Heat Treatment_2

Method

Factor coding (1; 0)

Factor Information

Factor	Type	Levels	Values
Material_2	Fixed	2	Hf; Lp
Heat Treatment_2	Fixed	3	Q1; Q2; Q3

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Material_2	1	43,10	43,100	7,59	0,008
Heat Treatment_2	2	843,97	421,985	74,30	0,000
Material_2*Heat Treatment_2	2	123,02	61,509	10,83	0,000
Error	54	306,69	5,680		
Total	59	1824,86			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
2,38317	83,19%	81,64%	79,25%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	47,647	0,754	63,22	0,000	
Material_2					
Lp	-2,94	1,07	-2,75	0,008	3,00
Heat Treatment_2					
Q2	12,99	1,07	12,19	0,000	2,67
Q3	6,64	1,07	6,23	0,000	2,67
Material_2*Heat Treatment_2					
Lp Q2	-5,75	1,51	-3,82	0,000	3,33
Lp Q3	0,60	1,51	0,40	0,694	3,33

Regression Equation

Hardness (HRC)_2 = 47,647 + 0,0 Material_2_Hf - 2,94 Material_2_Lp + 0,0 Heat Treatment_2_Q1
+ 12,99 Heat Treatment_2_Q2 + 6,64 Heat Treatment_2_Q3
+ 0,0 Material_2*Heat Treatment_2_Hf Q1
+ 0,0 Material_2*Heat Treatment_2_Hf Q2
+ 0,0 Material_2*Heat Treatment_2_Hf Q3
+ 0,0 Material_2*Heat Treatment_2_Lp Q1
- 5,75 Material_2*Heat Treatment_2_Lp Q2
+ 0,60 Material_2*Heat Treatment_2_Lp Q3

Fits and Diagnostics for Unusual Observations

Obs	Hardness (HRC)_2	Fit	Resid	Std Resid	
23	60,120	54,287	5,833	2,58	R

R Large residual