Investigation of Malaysian Parang Manufacturing Quality Variation with respect to Chemical, Mechanical and Physical Properties

by

Zulfadhli B Zarawi

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

_____

(Associate Professor Dr. Pathi bin Hussain)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ZULFADHLI B ZARAWI

ABSTRACT

The use of parang, which is defined as Malaysian machete is very wide throughout ancient times until today. The history of it tells that parang is an essential tool for everyone since it is used for the life purpose of the old time people in every aspect such as to serve as a weapon for protection and also as a tool for chopping, carving and many more. Nowadays, the use of parang is still being applied among Malaysian for the purpose of life. Moreover, there are also a lot of parang have been commercialized and been as one of the attraction for the tourist to look for. In relation to the rapid production of parang by days, the quality and performance of it is questioned in here. This is because every parang that is produced and to be sell usually is not equipped with any quality note or charts with it. The process of making parang which involves exposure of the metal to a very high temperature furnace for a long time and also hammering process to shape it will lastly produce parang of varied quality and performance. This is mainly due to the non-standardized steps taken in the processes involved. Some of the parang might undergo a longer exposure to the furnace compared to the others and this will affect the material properties that will then, affect the quality and performance. To accomplish the objective, two (2) tests are going to be conducted which are microstructure and hardness test. The microstructure test can be carried out by utilizing the use of Optical Microscope (OM). Meanwhile, Vicker Hardness Tester machine is used to test for the the hardness of the sample. The results from all of these tests will be collected and discussed.

ACKNOWLEDGEMENT

First and foremost, I would like to express my praises to ALLAH for His blessing.

My deepest appreciation and gratitude is extended to my supervisor, AP Dr. Patthi Hussain and the co-supervisor, Ir. Dr. Abd Halim Shah B Maulud for being very encouraging, supportive and responsive throughout the whole process of completing this final year project to fulfill the university requirement. Without their constant supervision and guidance, I may not be able to complete this project successfully.

Besides, thank you to the Final Year Project (FYP) 2 coordinator, Dr. Azmi Bin Abdul Wahab for being very dedicated and stringent in handling the course effectively throughout the year. The management of the FYP is systematic and every submission datelines are perfectly scheduled.

Hereby, I would like to also thank my fellow friends who have always been accommodating and cooperative whenever I am in need of ideas and opinion throughout the completion of this project report. Last but not least, I would like to acknowledge my family members for keeping me motivated throughout the year.

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TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Every present countries or places throughout the world nowadays have their own assets of attraction; either by doing development on current resources, or maintaining what did they had on history. Those assets mentioned are functioning to bring the owner too many purposes of benefit, such as for attracting tourists, earn profits on sale, display in exhibition, and just simply for keeping the sentimental value. Malaysia, as one of the developing countries in Asia Pacific region, had been focusing on plenty of businesses and urbanization to achieve the target of being a well-developed flourishing company by year 2020. Despite of the developing the current major resources they had, for instance oil and gas industries, Malaysia, which can be classified as very dependent on natural resources to survive since long time ago, did promoted the historical assets as well to assist on the development part.

Since the ancient days of Malaysia, parang has been used widely among the citizen for many purposes of life and it is still been used nowadays. In addition to that, the manufacturing of parang at some places such as Bidor in Perak and Bera in Pahang become vital to the domestic people for the sake of source of income and the identity they are proud of. Even though the manufacturing of parang grown rapidly at those stated places, up until today there are no such essential researches on the whole process of parang manufacturing had been documented.

In this project, the quality variation of Malaysian made parang is going to be investigated with respect to its mechanical, physical, and chemical properties. The raw material that is usually being used for making parang is the used automotive leaf spring, which is bringing in some uncertainties in its initial properties due to the long-time usage on vehicles. The processes of making parang may change the properties of the leaf spring. However, the changes in the properties of the leaf spring are not known and might be fluctuating, because of the non-standardized steps in the process of making parang. In addition to that, the properties of the final product, which is the parang itself, might be diverged as well due to the non-

standardized steps in the process of making it and thus, the quality of the parang has become a subject of variation that need a clear clarification for future betterment.

1.2 Problem Statement

Parang was a very essential tool in Malay traditional lifestyle and remains useful in today life. It has several blade edges for different cutting functions such as skinning, chopping, and carving which classifies parang as a multi-purposes tool during the traditional era. Currently, parang manufacturers are typically using used automotive leaf spring to reduce the feedstock costs. Leaf spring is an excellent material for making parang because it provides sufficient hardness and strength if properly processed.

However, the usage of used leaf spring might lead to different metal and carbon composition which might affect the final product performance of the composition varies significantly. In addition, the final product quality is also affected by the hardening and tempering processes.

1.3 Objective

As mentioned in Section 1.1 above, the aim of this research has been pointed out, which is to investigate the parang quality variation among the Malaysian manufacturers with respect to mechanical, physical, and chemical properties. In order to achieve the main goal, two objectives have been outlined which are as follows;

- To conduct metallurgy studies on sample of parang to conclude the properties it inherits.
- To relate the steps taken in process of making parang with the variation of its properties and quality.

Therefore, at the end of this project, the predetermined objectives are expected to be achieved within the given scope and time frame as per next discussion.

1.4 Scope of Study

In order to ensure this research is well focused and remains on its right track, the scope of study has been delineated. This project is mainly focusing on the laboratory experiments in favor of obtaining the acquired properties. The study on the mechanical properties will only focus on the hardness of the sample material and a hardness test will be conducted using hardness tester. The detailed study on metallography is very essential for observing and analyzing the microstructure of the sample material, the machines to be used are optical microscope.

1.5 Relevancy of Project

From this project, the quality variation of Malaysian parang manufacturing is studied in hope of bringing the industries into a higher level of excellence in producing a good parang. This project may as well, give ease to the people to choose the best parang of different purpose depending on the quality of the parang.

1.6 Feasibility of Project

This project is classified as feasible much since in involve the experiments and tests which require the utilization of equipments available and provided in the university. The implementations of the experiments and tests follow the theories, which become the fundamental to complete the project. The allocation of financial part as per declared for this project is sufficient enough since there will be no major cost involved especially on the purchasing part. In a nutshell, the author concluded that this project is feasible within the given period.

CHAPTER 2

LITERATURE REVIEW

2.1 Parang

Parang, initially is a Malay word that is now been acknowledged and exist in Oxford Dictionary, gives a meaning of a Malayan machete [14]. The function of parang is to serve as a tool for the uses of daily activities such as cutting, skinning, chopping, and carving. Figure 1 briefly depicts the overview and labelling of a parang [3].

Figure 1: Overview of a parang

2.2 Leaf Spring

It is absolutely known that the raw material that is used by a smith to make a blade, machete, or parang is the leaf spring in favour of its sufficient hardness and strength. A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles [17]. The leaf springs are crucial suspension elements on vehicles, necessary to minimize the vertical vibrations, impacts and bumps and create a comfortable ride [16]. There are three types of commercially used leaf springs nowadays which are steel leaf spring, composite leaf spring, and composite leaf spring [15]. Steel leaf spring is the one that is used to make a parang. The properties of parang to be studied might be different with the properties of the leaf spring used to make the parang due to the manufacturing processes carried out. The materials used for making the leaf spring itself are varied depending on the application [1]. The materials used for making the leaf springs are principally, SAE-1080, 1095,

5155-60, 6150-60 and 9250-60 [1]. Figure 2 below shows a visual appearance of the automotive spring leaf [6].

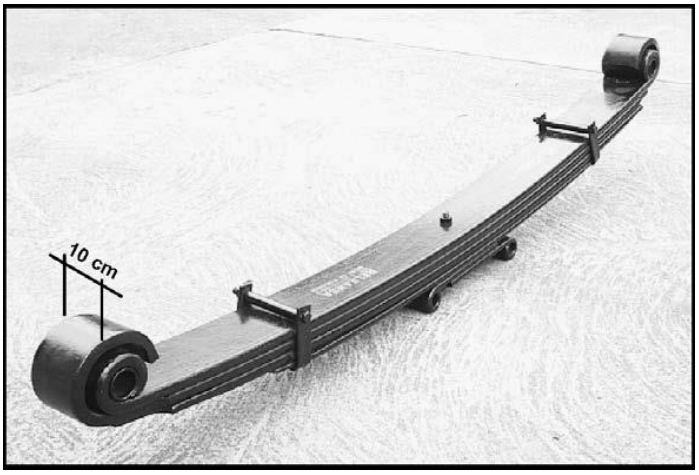

Figure 2: Visual appearance of the leaf spring

2.3 Hardness

The scope of mechanical properties to be studied in this project is narrowed down to focus on the aspect of hardness of the material sample. The definition of hardness is the resistance of a smooth-faced material to scratching and abrasion [5,8]. In the industry of parang manufacturing, hardness of the material is significant to produce a parang with good physical quality such as sharp and long-lasting. In the current marketplace there is much that is said about the hardness of parang. In fact there is customer resistance to production of swords that are not hitting certain benchmarks on specific hardness scales [8]. There are three (3) main options for testing a material's hardness in mechanical engineering study of material properties which are Brinell hardness (HB) measurements in accordance with ASTM 110, Rockwell C hardness (HRC) measurements following ASTM E18, and Vickers scale [6,8]. The resulting indentation depth determine the measurement of the hardness of a material [10,13]. As pointed out by Fuentes, J., et al. (2009), in their research, the hardness of a sample of leaf spring obtained is 397HB averagely, however, the measured values were rather disperse and some as low as 364HB due to the occurrence of uncontrolled local heating of the spring, resulting decarburization and softening during the manufacturing process.

2.4 Carbon Composition

The scope of chemical properties to be investigated on the material in this project is narrowed down to focus on the composition of the carbon content in it. The mixture of variable carbon content would regulate the hardening results possible in a blade [8]. The material would also produce, in heat-treatment, a hardness that would differ dramatically from one point on a blade to another [8,9]. Carburizing has been used widely in industry to improve surface hardness and fatigue resistance of steel parts while the toughness of the core is maintained [2]. Among the applicable methods to analyse the composition of a metal are Eddy current non-destructive method, atom probe tomography and optical emission spectrometer [2,6,12]. From the work of Fuentes, J., et al. (2009), the carbon content was lower on the surface of steel leaf spring than on the inside of it (0.48% versus 0.64%) due to decarburization process during the manufacturing process.

2.5 Comparison on Raw Materials for Making Parang

Table 1: Comparison on list of materials for making parang

	Spring Steel (SAE 5160)	**Tool Steel (AISI O1)**	**High Speed Steel (AISI M2)**	**Martensitic Stainless Steel (AUS-8A)**
Hardness (HRC)	40-45 [21]	55-64 [19]	62-66 [19]	58-62 [19]
Tensile Strength (MPa)	722.6 [21]	620.5 [21]	641.0 [18]	560.0 [20]
Carbon Composition (%)	0.56-0.64 [19]	0.85-1.0 [19]	0.95-1.05 [19]	0.70-0.75 [19]

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the research method that will be used is explained in section 3.2. Section 3.3 will explain on the sample preparation and will be followed with the explanation on experimental tests to be conducted accordingly.

3.2 Research Methodology

In this study, three samples of parang of different brand, bought at different places are used as the material for analysis. These samples of material will then have to be mounted for the ease of conducting test. Optical Microscope (OM) is going to be used to do the analysis for the microstructure of the material and hardness test is going to be conducted to analyze the hardness of the material. All of the tests and experiments are going to be conducted to compare the variation of results for the three different parangs at three different positions at each parang. The flow chart in Figure 3, which is the iterative process of the experiment and the investigation, will be described accordingly. Data analysis and final result section are discussed later in the next chapter.

Parang A

Manufactured by Chop Kwong Yuan Loong, Bidor, Perak.

Bought directly from the factory.

Figure 3: Parang A

Parang B

Manufactured by AAA Jing Yung Lee.

Bought at Seri Iskandar, Perak.

Figure 4: Parang B

Parang C

Unknown manufacturer.

Bought at Batu Gajah, Perak.

Figure 5: Parang C

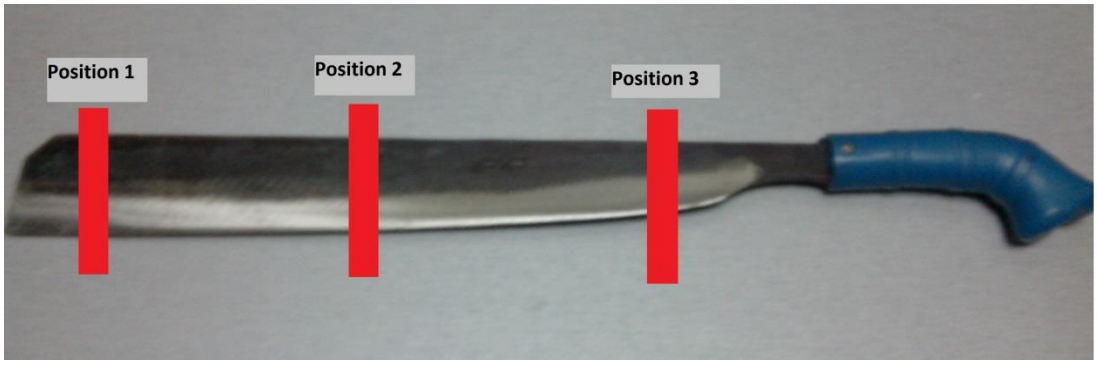

Figure 6: Positions of interest to study

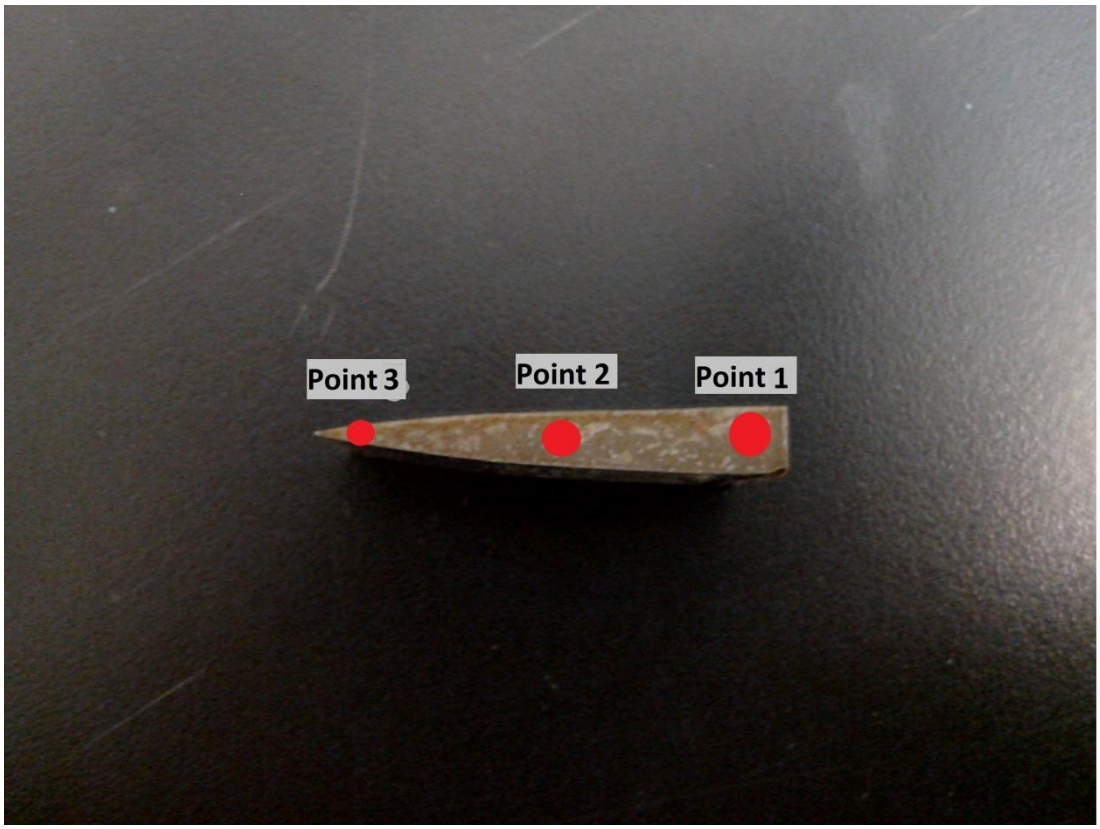

Figure 7: Points of interest to study on the surface of cross sectional of the parang

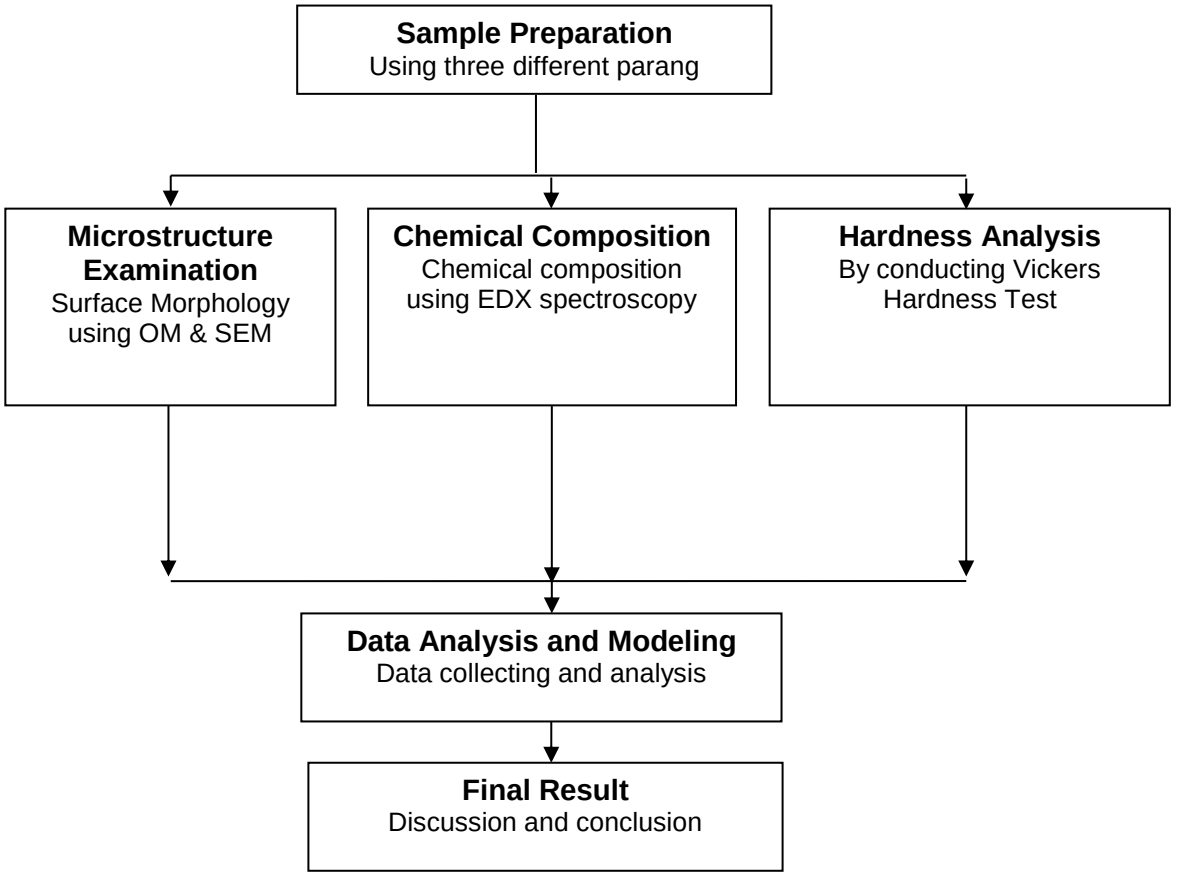

Figure 8: Flow Chart

3.3 Sample Preparation

The material that will be used is three different brand of parang bought at different places of each as per shown above. The procedures taken are as per below:

1. Each parang is cut into three parts which are bottom part, middle part, and end part as per shown in Figure 6 above. These three parts are the positions of interest to be studied in this project.
2. Electrical Discharge Machining Wire Cute (EDM Wire Cut) is used for the cutting part.
3. Then, all of the samples are mounted using Auto Mounting Press machine for the function of easier and better handling of the samples.
4. The samples' surface are then be ground on 120, 220, 500, 800, 1000, 1200 grit SiC papers, and then polished using 1 μmAl2O3 pastes to the mirror finish.

Figure 9: EDM Wire Cut Machine used for cutting the samples

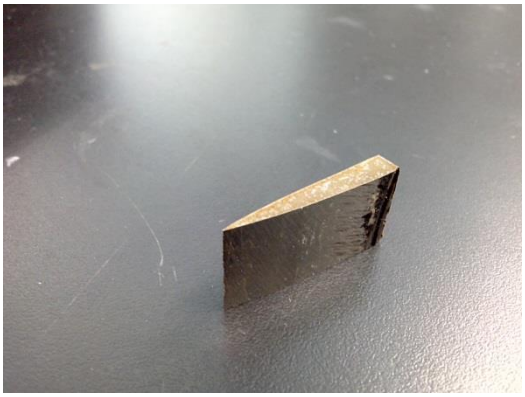

Figure 10: Sample of parang after being cut

Figure 11: Auto Mounting Press machine used for mounting the samples

Figure 12: Sample that has been mounted

Figure 13: Grinding and Polishing Machine used for surface finishing of the samples

3.4 Microstructure Analysis

The purpose of this test is to determine the pattern of microstructure of each sample of the parang and thus, to come out with comparison according to the part of the parang. There are three points of interest on the surface of the sample to be studied as per shown in Figure 7. This test is conducted using Optical Microscope (OM). The procedures were as follow;

1. Before conducting the microstructure examination, the samples are mounted, grinded, polished and etched. Mounting of specimen is required so that it is more convenient during grinding and polishing.
2. After mounting, the samples need to be grinded and polished.
3. Then, the samples need to be etched by using etchant. The purpose of etching is to reveal the grain boundary. As the material of the parang is carbon steel, then the corresponding etchant used is Nital.
4. Nital is prepared by dissolving 50 ml of ethanol and 3 ml of Nitric Acid. The Material Safety Data Sheet (MSDS) is attached in Appendices for references.
5. After that, the specimen is washed by using ethanol and then dried.
6. Then, Nital is applied onto the surface of the sample by swabbing for 20 seconds.
7. Lastly, the specimen is washed using water and ethanol. The specimen is let to dry and ready for microstructure examination.

3.5 Hardness Test

The Vickers hardness test method, also referred to as a microhardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers method is based on an optical measurement system. The microhardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from a few grams to one or several kilograms, although "Macro" Vickers loads can range up to 30 kg or more. For this project, a constant load of 300gf is applied at dwell time of 15s for the test on three (3) different points on the samples. By that, the comparison and variation of hardness of each sample of the parang can be obtained to relate with the variation of quality and performance.

3.6 Gantt- Chart and Key Milestones

Table 2: Project Gantt Chart and Key Milestones for FYP 1

Training Activities	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Topic Selection	❖	❖												
Literature Review														
Study about parang														
Submission of Extended Proposal						❖								
Laboratory equipment familiarization and experiments														
Research and Find Materials														
Proposal Defence								❖						
Interim Report Preparation														
Interim Report Draft Submission													❖	
Interim Report Submission														❖

❖ Milestone

Progress

Table 3: Project Gantt Chart and Key Milestones for FYP 2

Training Activities	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Sample Preparation															
Microstructure Examination															
Submission of Progress Report								❖							
Hardness Test															
Chemical Composition Examination															
Pre Sedex Poster Presentation											❖				
Submission of Draft Dissertation												❖			
Submission of Dissertation and Technical Paper													❖		
Oral Presentation														❖	
Submission of Hard Bound Dissertation															❖

❖ Milestone

Progress

CHAPTER 4

RESULT AND DISCUSSION

4.1 Microstructure Analysis

In order to reveal the microstructure level of the samples, the author utilized the Optical Microscope (OM) to observe the microstructures of all of the samples of the parang. The microstructures of all the samples were observed and analyzed at magnification of 500X. By average, the results obtained were slightly almost constant for all of the samples. Pearlite and ferrite structure were regularly can be seen at point 1 of the sample, meanwhile, at point 2, some of the samples have the same structure as point 1 and some of the other samples have retained austenite structure instead of ferrite as well as even the martensite can be seen. At point 3, by average, most of the samples have the martensite structure although the appearances and dimensions varied.

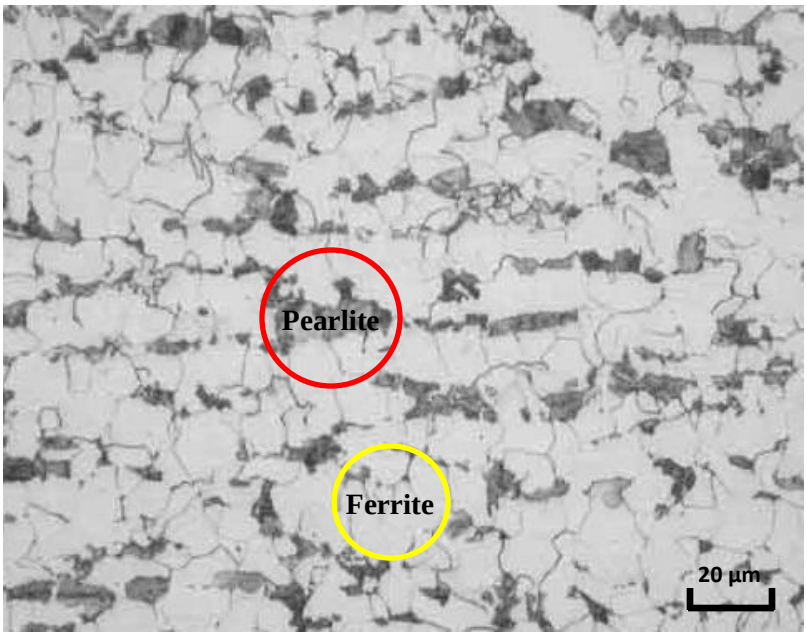

Figure 14: OM image for Parang A at point 1 on position 1

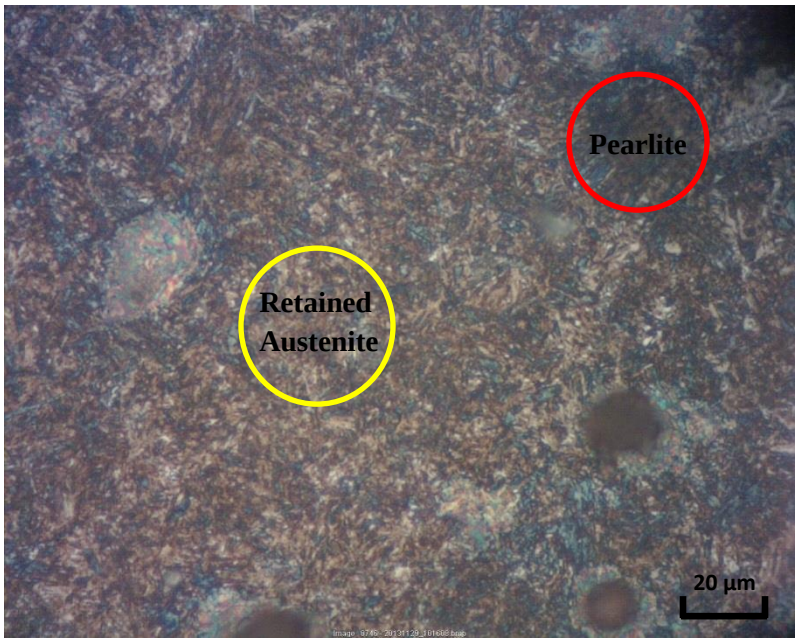

Figure 15: OM image for Parang A at point 2 on position 1

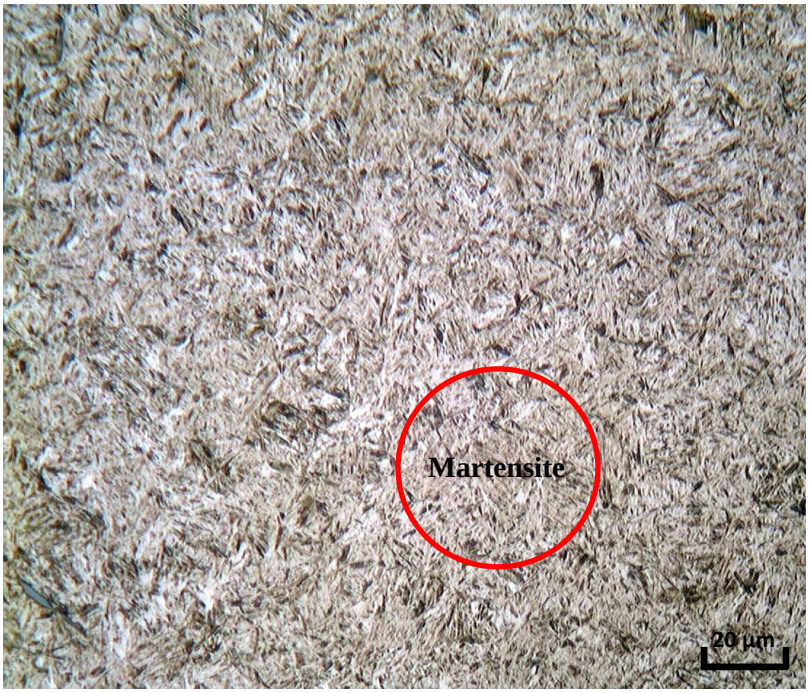

Figure 16: OM image for Parang A at point 3 on position 1

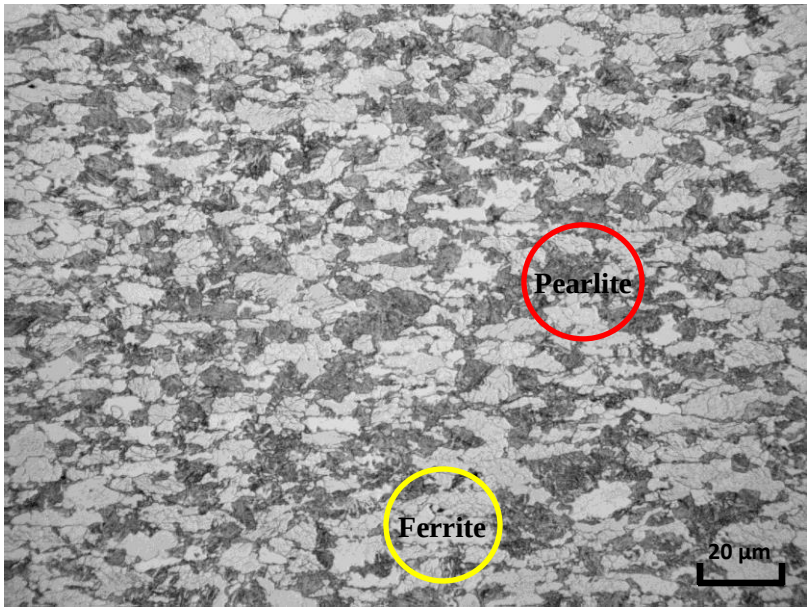

Figure 17: OM image for Parang A at point 1 on position 2

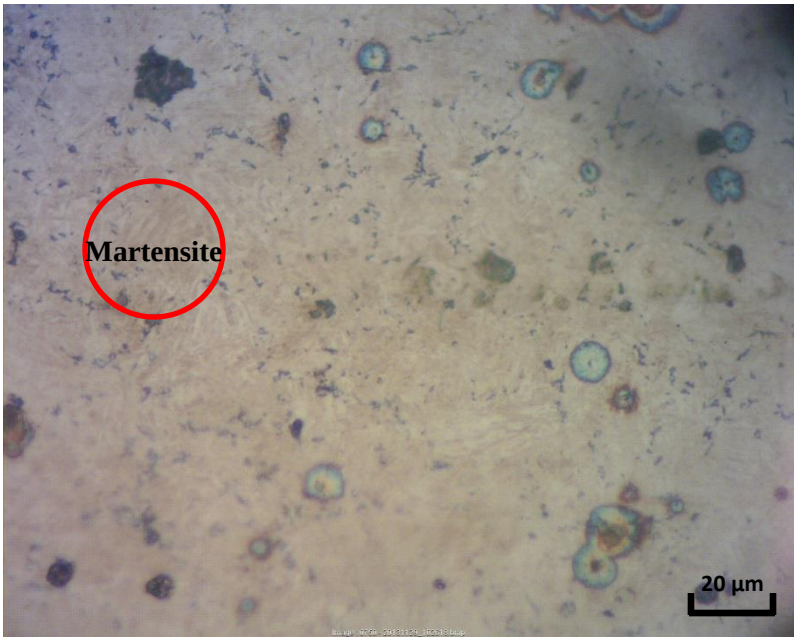

Figure 18: OM image for Parang A at point 2 on position 2

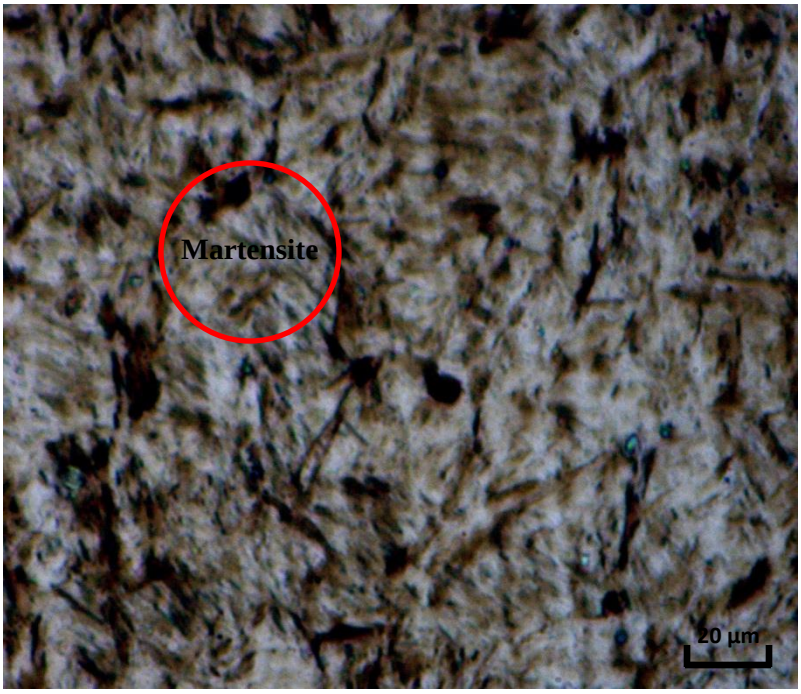

Figure 19: OM image for Parang A at point 3 on position 2

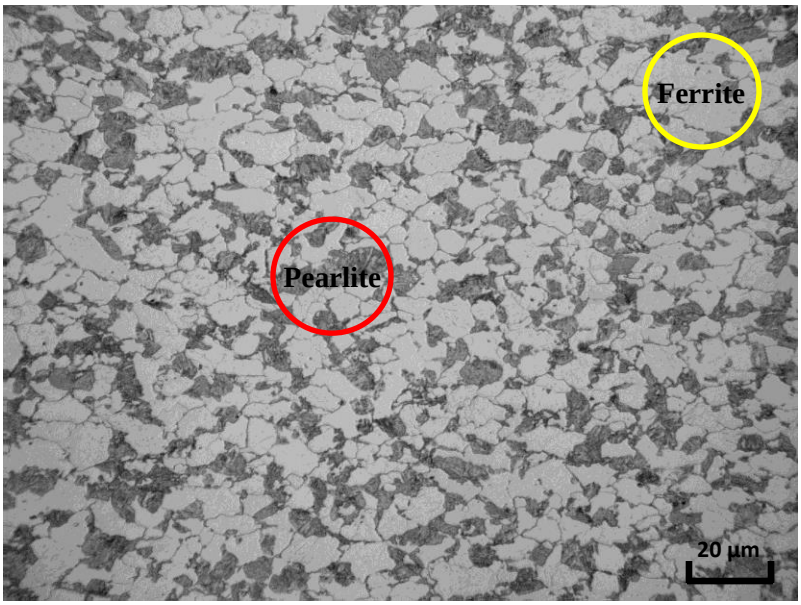

Figure 20: OM image for Parang A at point 1 on position 3

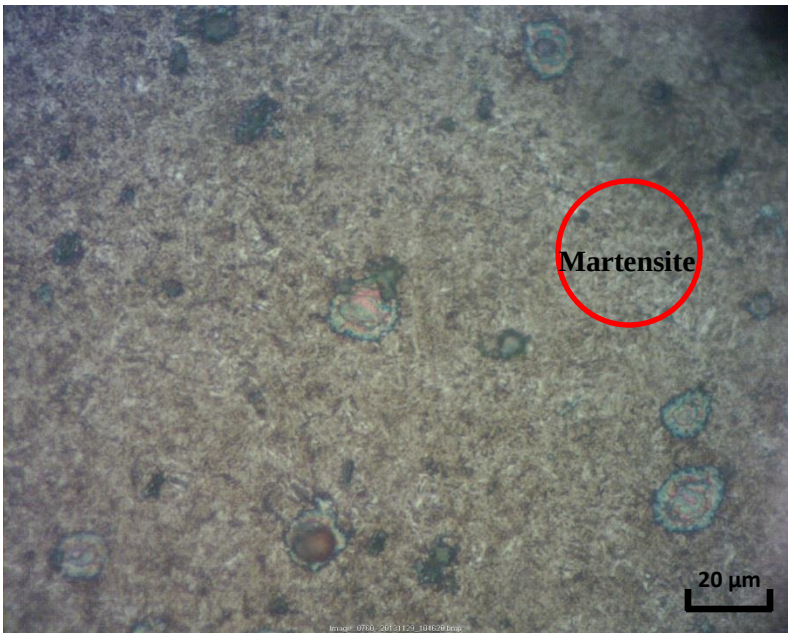

Figure 21: OM image for Parang A at point 2 on position 3

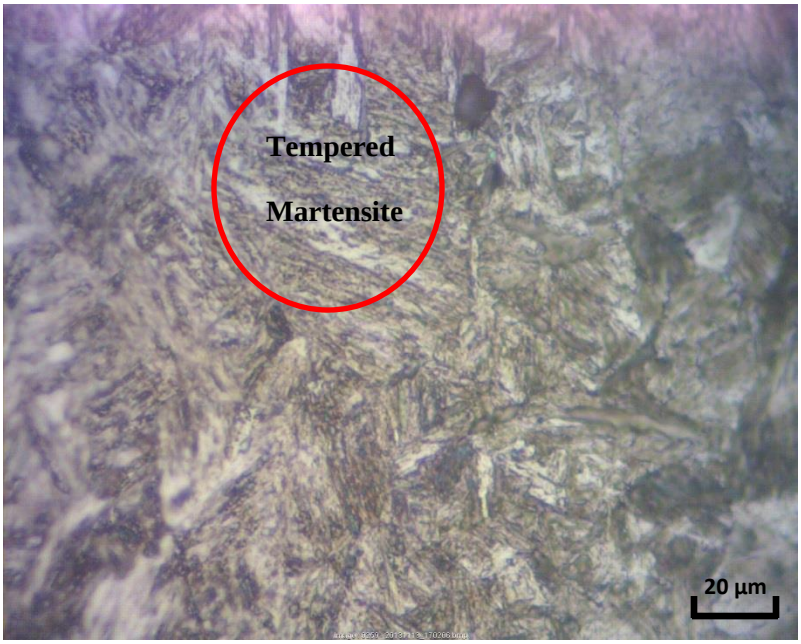

Figure 22: OM image for Parang A at point 3 on position 3

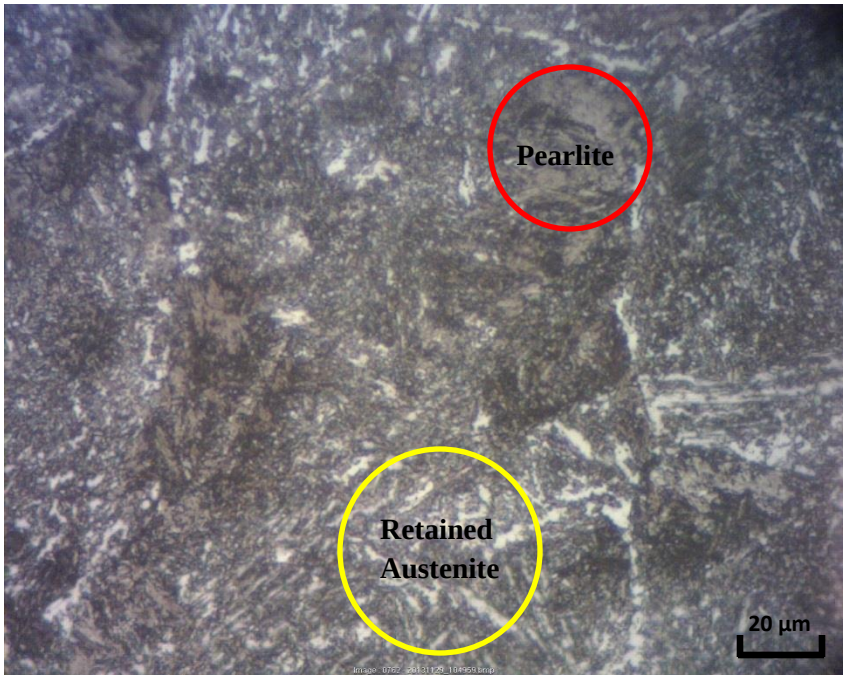

Figure 23: OM image for Parang B at point 1 on position 1

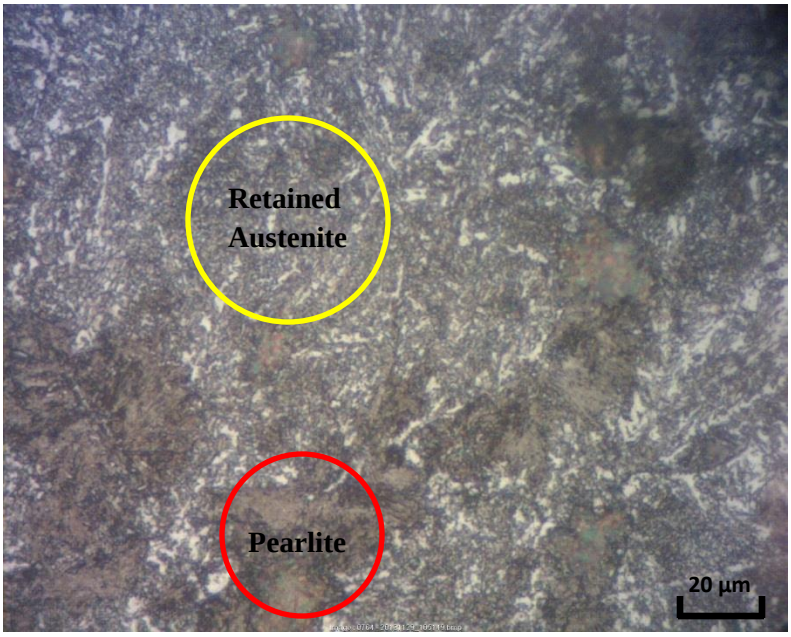

Figure 24: OM image for Parang B at point 2 on position 1

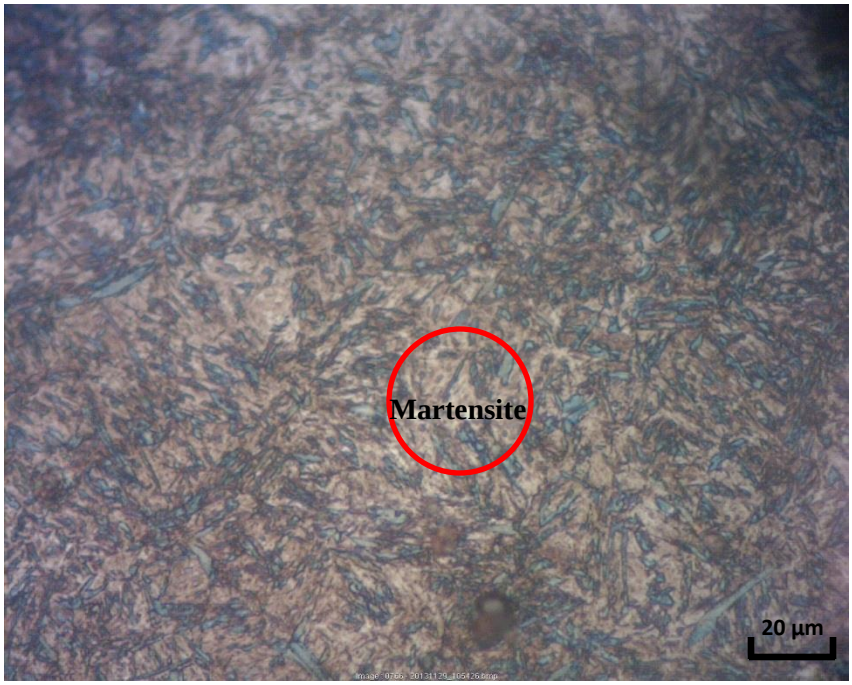

Figure 25: OM image for Parang B at point 3 on position 1

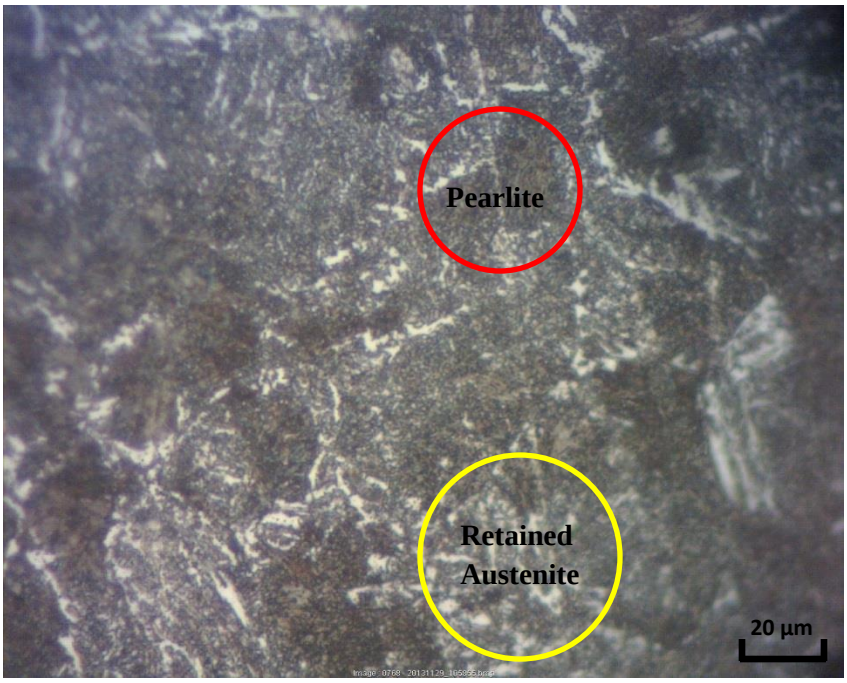

Figure 26: OM image for Parang B at point 1 on position 2

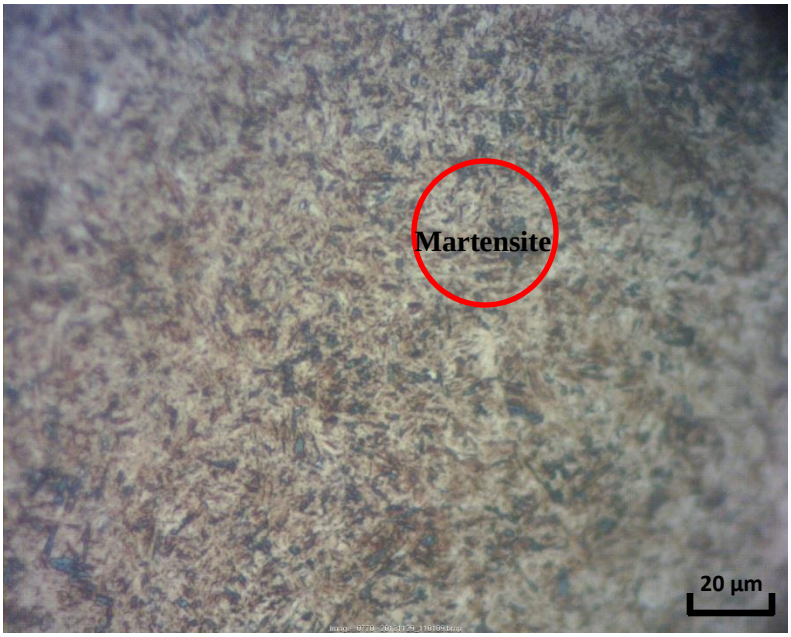

Figure 27: OM image for Parang B at point 2 on position 2

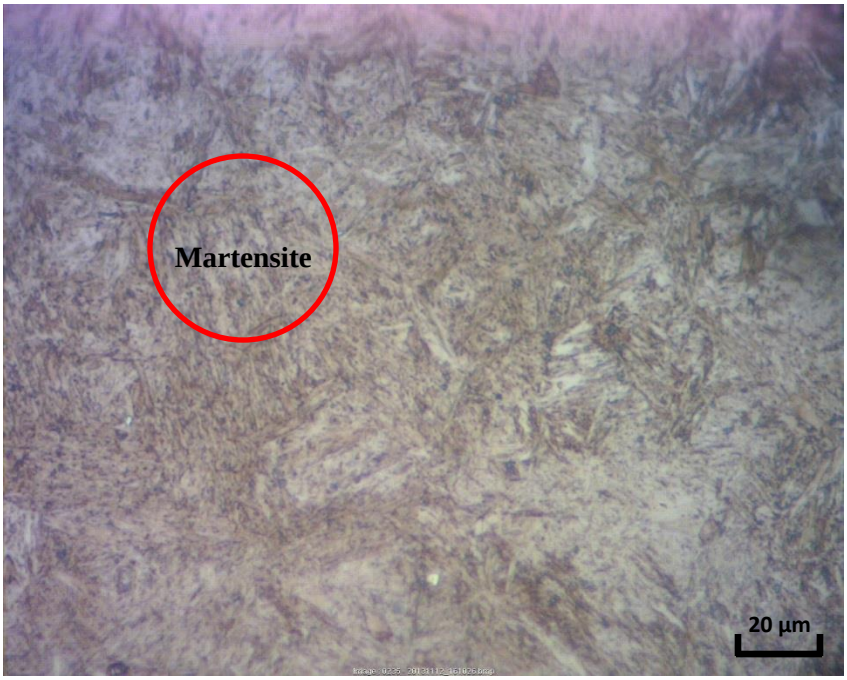

Figure 28: OM image for Parang B at point 3 on position 2

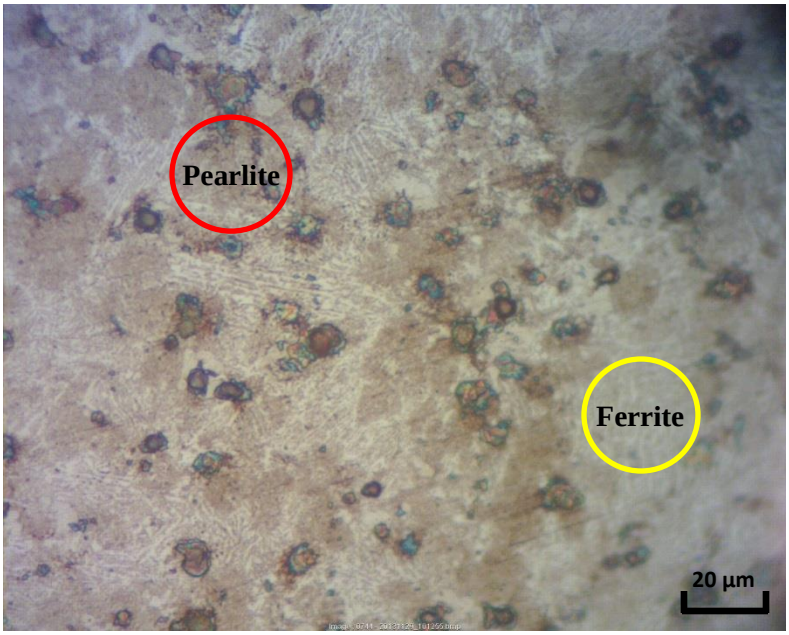

Figure 29: OM image for Parang B at point 1 on position 3

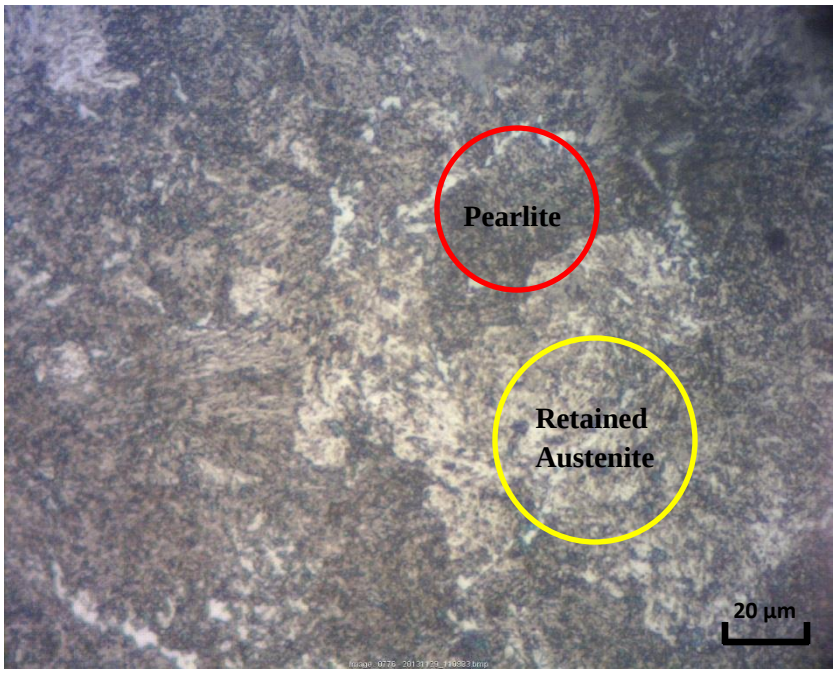

Figure 30: OM image for Parang B at point 2 on position 3

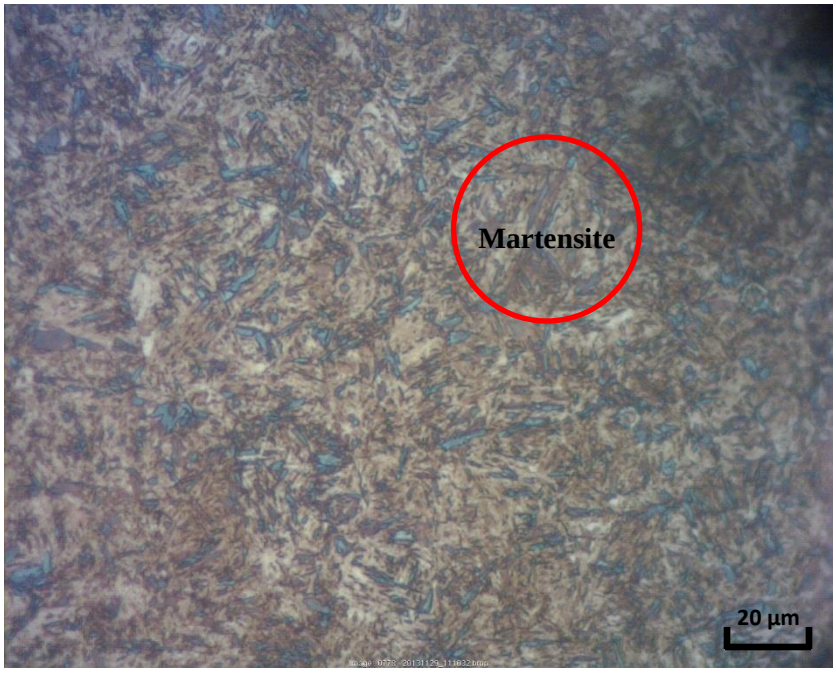

Figure 31: OM image for Parang B at point 3 on position 3

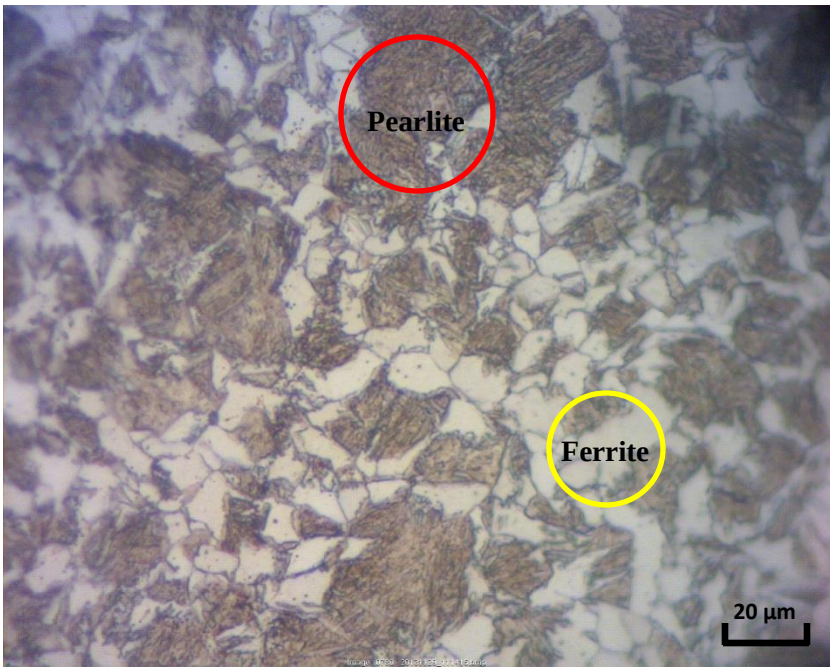

Figure 32: OM image for Parang C at point 1 on position 1

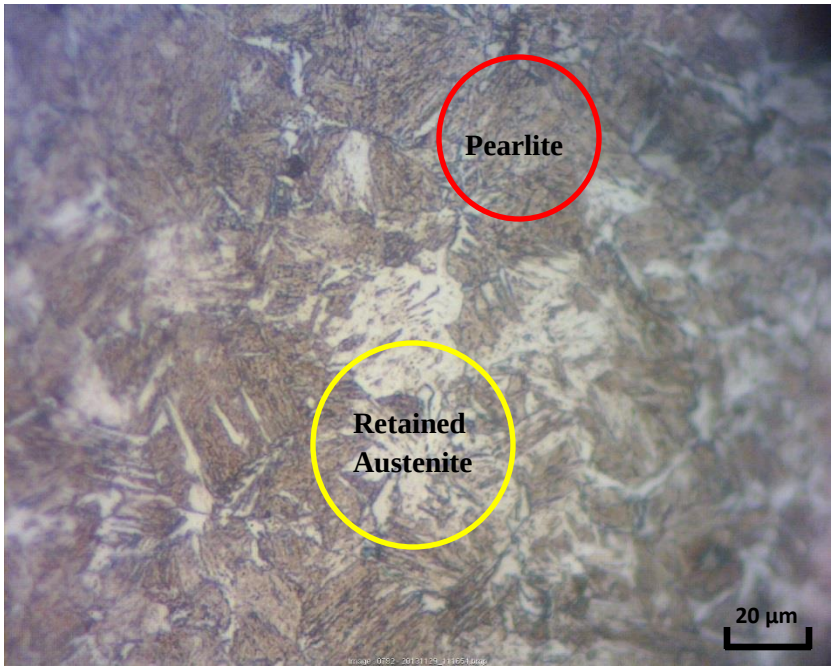

Figure 33: OM image for Parang C at point 2 on position 1

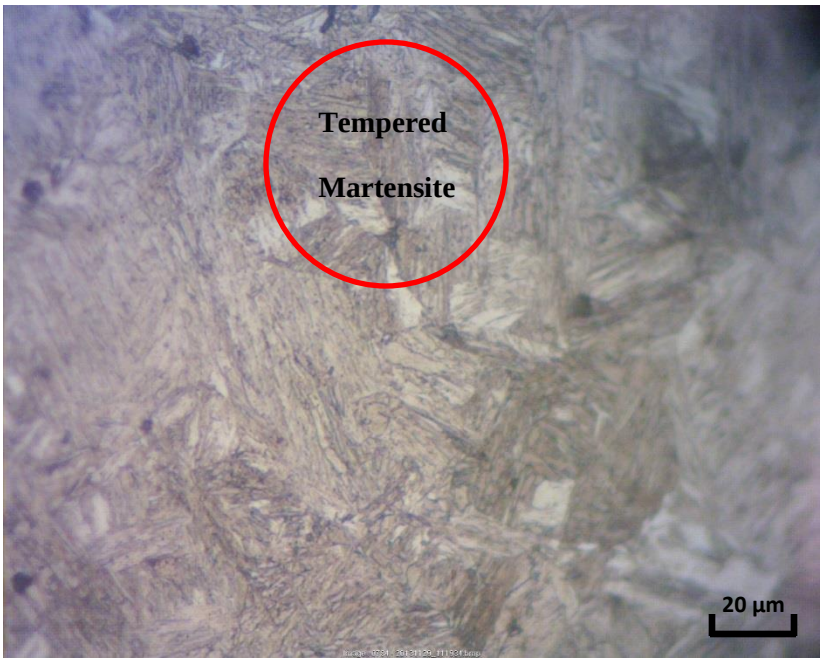

Figure 34: OM image for Parang C at point 3 on position 1

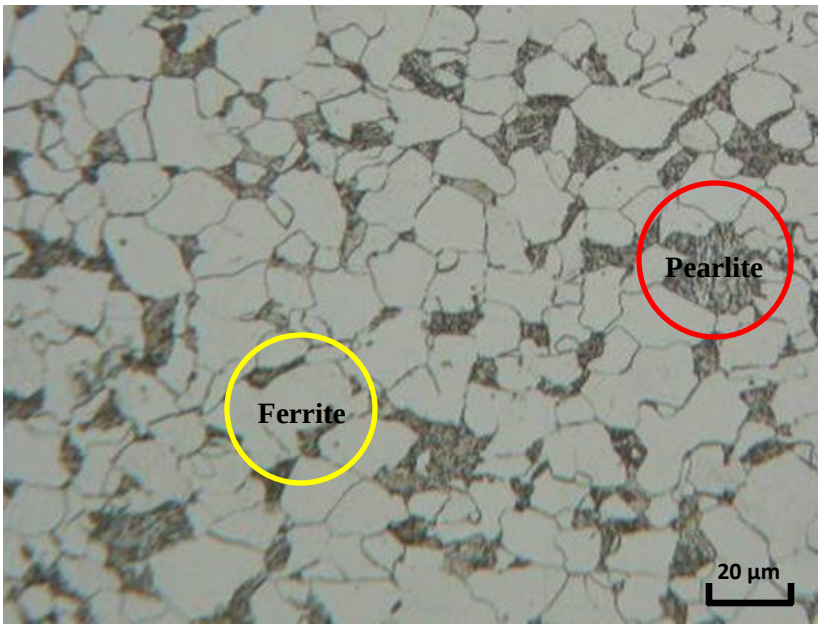

Figure 35: OM image for Parang C at point 1 on position 2

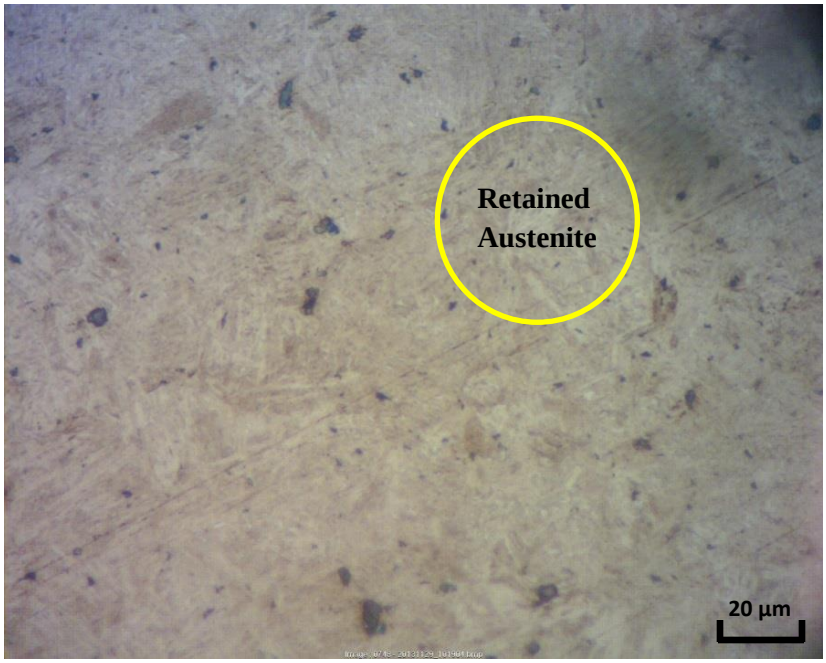

Figure 36: OM image for Parang C at point 2 on position 2

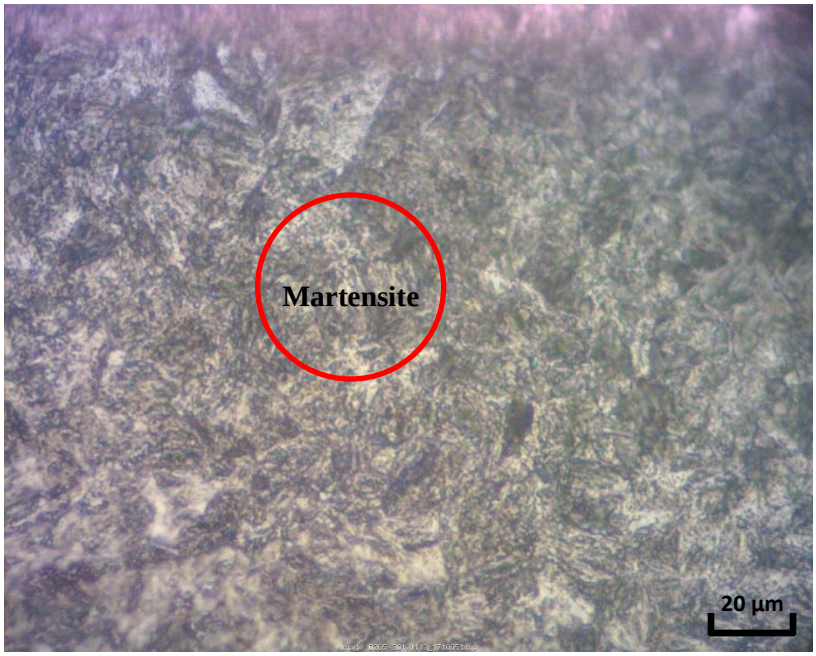

Figure 37: OM image for Parang C at point 3 on position 2

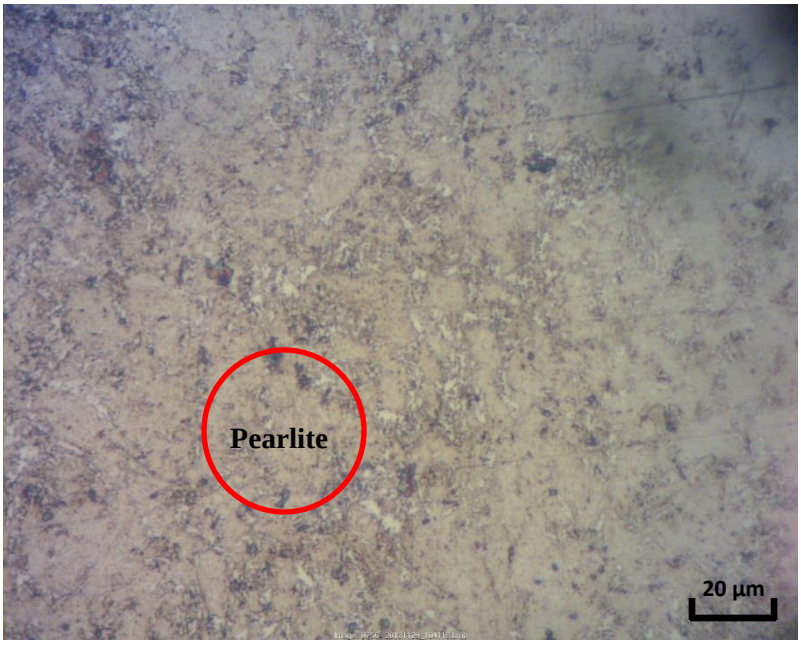

Figure 38: OM image for Parang C at point 1 on position 3

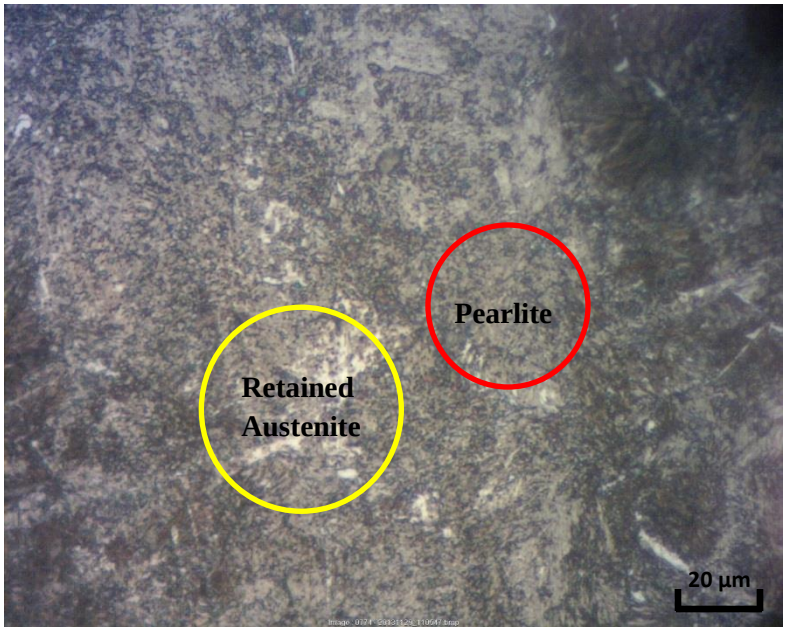

Figure 39: OM image for Parang C at point 2 on position 3

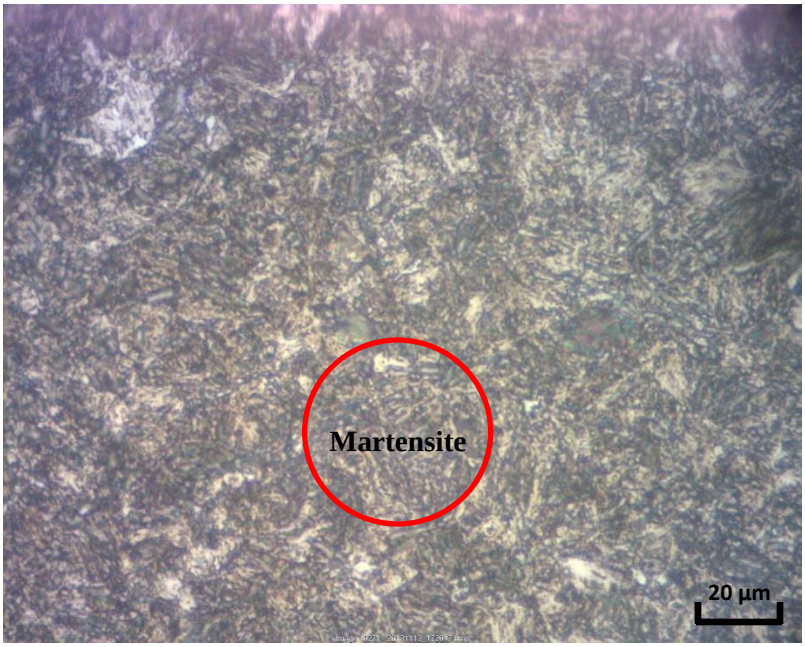

Figure 40: OM image for Parang C at point 3 on position 3

The observations and analysis carried out on the micrograph of each sample of the parang have indicated the variation of properties it inherits. The variation in the process of manufacturing the parang influenced the variation in the micrograph obtained. Briefly, the process of making parang involved the process of heat treatment such as austenizing, quenching, and lastly tempering. However, the subjective parameters of each of the process such as the intensity, duration, and temperature are not constant during the manufacturing of different parang. Due to this variation, the quality of the different parang can be visualized with the micrograph obtained.

Pearlite and ferrite structure are seen on most of the sample at point 1 of it except for point 1 on position 1 and position 2 of Parang B. Pearlite is a combination of ferrite and cementite. Pearlite grain structures resemble human fingerprints. Steel with exactly 0.77 percent carbon consists of uniform pearlite at room temperature. The thin plate pearlite is formed due to the fast cooling process of the steel after heating for shaping purposes. The ferrite is formed due to complete transformation from its austenitic phase during cooling. It has a Body Centre Cubic structure (B.C.C) which can hold very little carbon which is typically 0.0001% at room temperature. Ferrite gives a material the magnetic, hard, and brittle characteristics.

Retained austenite structure is found at point 2 of all samples except for point 2 on position 2 and position 3 of Parang A as well as point 2 on position 2 of Parang B which showed the martensite phase. Retained austenite is the austenite that does not transform to martensite after the quenching process. The property that is carried by retained austenite is the intermediate of combination of mixture of soft and tough austenite with hard, strong, and brittle of martensite. Since retained austenite can increase the impact toughness of a material, the presence of it at point 2 of any part of the parang is very essential to serve as supporting part to absorb the impact applied in prior to prevent crack to the parang.

Martensite phase is found at point 3 of all samples except for position 3 of Parang A and position 1 of Parang C which shows the presence of tempered martensite instead. Martensite can be formed from a rapid cooling process of austenitic phased steel. In this parang manufacturing process, the quenching part by putting the red-hot steel into oil

after burning it is the part of the process where martensite is formed on the parang. In addition, the martensite also can transform from its austenitic form by quenching and working by plastic deformations to reductions of area at this sharp part of the parang. Different with the austenite, martensite has a Body Center Tetragonal crystal structure (B.C.T). This results in a distorted structure that has the appearance of fine needles. There is no partial transformation associated with martensite, it either forms or it doesn't. However, only the parts of a section that cool fast enough will form martensite at which in a thick section it will only form to a certain depth, and if the shape is complex it may only form in small pockets. The hardness of martensite is solely depends on carbon content, it is normally very high, unless the carbon content is exceptionally low. Tempered martensite, on the other hand is the martensite that undergoes tempering process. Due to the transformation to tempered martensite, the properties change as well, which are increased ductility and toughness of the material.

In the scope of microstructure study carried out on all of the samples of the parang, Parang C has shown the most consistent and reliable quality out of the other two parang. This is due to the distribution of the phases throughout the each point at all positions of it. At point 1, pearlite and ferrite phase is present constantly at all positions whereas at point 2 of all positions, retained austenite phase is present. However at point 3, there is a slight different where at position 1, the phase present is tempered martensite while the other position is martensite. This indicate that the intensity of quenching and tempering process to produce the part of point 3 is not equally distributed.

4.2 Microhardness Assessment Result

The variation of hardness at different points on different locations of all of the three parangs is tested by carrying out Vickers hardness test. This test was conducted to determine whether there will be different on hardness of the parang of different brand, as to compare which one is better. Vickers hardness tests were performed on the surface of the samples using Model HV-1000A Micro Hardness Tester with 300gf load and 15 s dwell time. According to the results obtained, which is presented on the table below, the value of surface hardness obtained for each sample is compared through the distance from the surface.

Table 4: Vickers hardness reading of all samples

Position	Point	Hardness (HV)		
		Parang A	Parang B	Parang C
1	1	317.8	277.8	431.4
	2	650.7	293.1	358.6
	3	529.9	302.8	423.6
	Average	499.47	291.23	404.53
2	1	734.8	307.6	265.9
	2	695.1	625.2	252.9
	3	754.4	662.0	384.3
	Average	728.1	531.6	301.03
3	1	447.2	304.4	213.6
	2	444.9	376.4	206.7
	3	621.0	641.9	319.5
	Average	504.37	440.9	246.6

Table 4 above shows the variation in terms of microhardness at different points on different positions for each parang. Similar with the microstructure analysis conducted previously, the variation in the process of manufacturing a parang did influenced the variation in the properties of a group of different parangs.

Considering the reliability and durability of a parang, Parang C has the best quality of them in terms of distribution of hardness at different points on different positions throughout the parang. As per can be seen from Table 4, averagely the hardest part on Parang C is at point 3, which is the sharp edge part where it first adapt to the impact with the material when chopping or cutting. Secondly hardest point is at point 1 which is at the top of the parang. This part should be hard to preserve the shape and orientation of the parang over a long range of using time. The middle part, which is at point 2 is the least hard point on Parang C. Due to this, point 2 has the greatest ductility and impact toughness although it is softer than the other points. The advantage is for point 2 to serve as the support to absorb the impact applied to prevent crack or failure on the parang to happen. Thus, for a long lasting parang, Parang C is the best among the three parangs that are studied in this project.

However, if strength and adaptability to rough usage are the preferred properties, then Parang A has the best quality of them. In despite of having a long lasting parang yet less strength, Parang A has the quality of the other way around. Parang A is the best to be used for hard and rough usage such as when chopping or cutting a very hard material. This is due to the greatest hardness acquired by Parang A. Based on Table 4, the hardest position on Parang A is at position 2 which is at the center of it. This is the regularly and preferably region of usage for any parang. Thus, for dealing with the best strength and adaptability to rough usage, Parang A is the best choice.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Based on the experiments and tests conducted throughout this project, the properties of Malaysian made parang manufacturing quality variation are clearly studied and analysed. There are still, some parts of this project that need improvement and enhancement to yield a better, more detailed, and more comprehensive result to come up with any improvements to be implemented to our Malaysian parang manufacturing industry. In a nutshell, this project lead to two (2) conclusions as per below:

- The phase present at a same point on different parangs is averagely similar to each other. However, there are still variations of it can be seen. These variations, in terms of size, orientation, and structure determine the characteristics inherited. These variations are there due to the inconsistent implementation of process during manufacturing of the parang
- Different parangs experienced different exposure to intensity or frequency of the same processes conducted during the manufacturing of them. Due to this, the quality in terms of hardness of different parangs, also varied differently. Depending on the purpose and necessity of the user, different parangs will give a different quality and satisfaction.

As for the future works, it is very interesting if a standard of parang which comprised of properties investigated in this project or any other properties can be produced so that the quality of parang produced will be cared of and the consumer will have at least a printed sheet of quality comparison of parang to buy the best parang for daily uses. By that, a deeper and detailed analysis of such as this can give a great impact to Malaysian parang manufacturing industry in the future.

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APPENDICES

Appendix 1. ASTM E-384 Microhardness Guidelines

Hardness Testing and Specimen Preparation

Struers

Application Notes

1. Introduction

Hardness testing is a useful tool for the evaluation of materials, quality control of manufacturing processes and in research and development work. It gives an indication of a material's properties, such as strength, ductility and wear resistance. In this application note we will consider the indentation hardness which is defined as: a measure of a material's resistance to plastic deformation, when a hard indenter penetrates into a softer material. The result obtained during testing will depend on the test used, i.e. the load and its duration, the type of indenter (geometry/material) and application of testing method. The hardness test used depends on the type of material, size of the part and its condition. Therefore, the method used should always be indicated together with the obtained result. There are different standards available which, if followed correctly, can secure a reliable result. Deviations from standard values, for example duration of test, should be noted in the hardness report. During hardness testing it is important to keep the parameters influencing the test under control in order to obtain accuracy and repeatability.

For metals, indentation hardness tests are employed. The most common tests in this category are Rockwell, Vickers, Brinell and Knoop. For Rockwell, the depth of penetration is used as a measure of the hardness while for Vickers, Brinell and Knoop, it is an optical measure of the size of the indent that is used. There are different standards available for all types of tests, in which the procedure/requirements for the actual hardness test are explained.

The hardness measurements can provide information about the material as a general quality control of material after processing or after heat treatments. Hardness tests are used in order to test hardenability of steel by Jominy testing, the hardened depth of surface hardened steel and controlling the performance of welds. Also there is a relationship between the hardness and yield stress/ultimate tensile stress, and the hardness test can give a qualified estimate of the mechanical properties [T, 2]. Another possible application is for ceramics/cermets/sintered carbides etc. where the fracture toughness (K_{IC}) can be determined by using Vickers hardness testing together with a relationship based on Palmqvist's formula [3].

Other categories of hardness tests are:

- A dynamic test of metals is the Scleroscope hardness test, where the height of rebound of a hammer is used as a measure of the hardness.
- For minerals, a scratch test in which a harder mineral scratches into a softer one.

- For instrumented indentation testing (IIT) both hardness and elastic modulus can be determined accurately. During loading and unloading, the load-displacement curve is recorded for determination of the modulus.
- Different indentation tests are also used for testing hardness in plastics, like Shore (Durometer), Rockwell, the Ball indentation hardness test and Barcol.

This Application Note will focus on hardness testing of metals, the mechanical preparation of the specimens and the different parameters influencing the indentation hardness testing result.

2. Preparation difficulties

Problem: 1
It can be difficult to obtain plane-parallel surfaces during preparation, see Figure 1. For instance, for Vickers (description see section 3, page 5), the measured diagonals should not deviate more than 5% from each other. Also the indenter should be perpendicular to the test surface and not deviate from this with more than 2° in order to give a reliable result.

Figure 1. Sketch of a) an unplane specimen, b) a plane-parallel specimen

Solution: 1
The best is to use a fixture to hold the specimen so that the indenter penetrates the surface perpendicularly, see Figure 2. If no fixture is available the mechanical preparation of the specimens need to result in plane-parallel end surfaces, see Figure 1b. It is possible to use the specimen holder MAXSO with a plane end surface, see Figure 3, in which the specimens are fastened by the use of double-adhesive tape, in order to achieve as plane-parallel specimens as possible. When using MAXSO it is important that the specimens are cut to approximately the same height. When using MAXCY, see Figure 3, the final plane-parallelism of the specimen surfaces depends highly on how the operator has clamped the specimens in the holder.

Figure 2. Fixtures to hold specimens during hardness testing. a) 1 x 40 mm diam., b) 8 x 30 mm diam

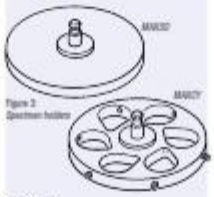


Figure 3
Specimen holders

Problem: 2
If the surface finish of a specimen is too rough, it might be problematic to evaluate the corners of an indent, especially if automatic equipment is used. A clean reflective surface is needed. Also the surface preparation should have a minimum influence on the properties of the material to be tested. The surface preparation needed is dependent on the type of test and the applied load. Micro hardness (loads lower than 1 kgf) requires a more polished surface. Rockwell tests are not as sensitive to surface preparation as the depth of penetration is measured and, not an optical measure of the geometry of the indent is performed, therefore no preparation or a ground surface can be sufficient.

If the surface is too rough, scratches from the preparation may cause a misreading of the indent size, when using automatic hardness testing. Note that softer materials are more sensitive to preparation artefacts since the same size of abrasives will introduce larger deformations/scratches in the surface than in harder materials, see Figure 4.

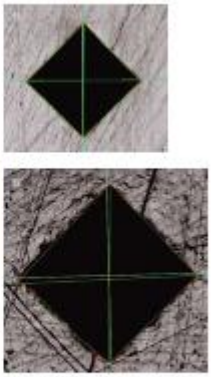


Figure 4. Vickers indents on the same rough surface preparation (9µm) for a) Hardened steel 715 HV 10 and b) 0.5% carbon steel 180 HV 10. Here 17% of the indentations of the carbon steel were discarded due to the rough surface, while no problems were encountered for the hardened steel.

Solution: 2
A polished surface should be used. Figure 5 shows the surface after final

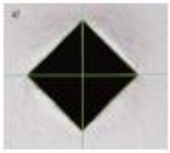


Figure 5.
Vickers indents on a smooth surface, MD-Plus DiaPro Plus, 3µm
a) Hardened tool steel, 715 HV 10
b) 0.5% carbon steel, 180 HV 10

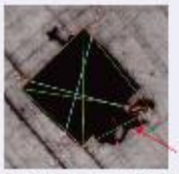


Figure 6. Dirt disturbing the automatic optical reading. Material is hardened tool steel. Vickers hardness test. Load 0.5 kgf[1]. Final preparation on surface MD-Largo with diamond suspension DiaPro Allegro/Largo (9 µm).

polishing with the MD-Plus cloth and the diamond suspension DiaPro Plus (3µm).

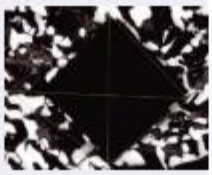
Problem: 3
If the specimen is not properly cleaned after mechanical preparation and an optical reading of the hardness test takes place, an automatic reading might result in a misinterpretation of the corners of the indent, see Figure 6.

Solution: 3
Always ensure that the specimens are cleaned properly, otherwise e.g. dirt or fibres from the polishing cloth might complicate the reading.

Problem: 4
For a heavily etched sample, it might be difficult to evaluate the corners of an indent, which may lead to a less accurate hardness value.

Solution: 4
Etching should, as far as possible, be avoided since it results in a less reflective surface. If etching is necessary, a light etch is preferable so that it will be possible to discriminate the corners of the indent. Sometimes, it can be necessary to etch, for example when evaluating a weld, see Figure 20.

[1] In this Application Note, the test forces are given in kgf (kilogram force), a unit introduced before the SI-system came in use. (1kgf=9.81N)



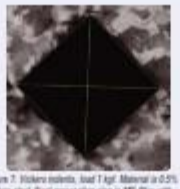


Figure 7. Vickers indents, load 1 kgf. Material is 0.5% carbon steel. Final preparation step is MD-Plus with diamond suspension DiaPro Plus (3µm). Etched with 2% Nital a) heavily etching b) light etching.

ZeissJet

3. Description of principles

For hardness indentation tests, where the size of the indent is determined optically, as for Vickers, Brinell and Knoop, the hardness is defined as the applied load divided with the contact area (for Knoop it is the projected area). The tests can be performed manually by using tables where the mean value of measured diagonals/diameters is converted into a hardness value or the value may be calculated based on a formula, or by an automatic hardness testing machine where the hardness is determined automatically.

Depending on the size of the applied load, the indentation hardness test can be divided into macro (also called general or universal) and micro hardness testing. For macro hardness testing, the test loads are 1 kgf (9.81 N) or larger, while micro hardness testing covers the load range from 1 gf to 1 kgf.

The required surface condition depends on the type of test and load used. For macro hardness usually a milled or ground surface is sufficient, sometimes no preparation at all is required. For micro hardness testing a polished surface

Table 1. Surface requirements for the different hardness indentation tests

Test	Surface Preparation
Rockwell HR	**Macro hardness test:** - no surface preparation or - ground
Brinell HBW	**Macro hardness test:** - milled, - ground or - polished
Vickers HV	**Macro hardness test:** - ground **Micro hardness test:** - polished - electropolished
Knoop HK	**Micro hardness test:** - highly polished

is needed, for very small loads even oxide polishing or electrolytic polishing might be needed.

The surface roughness has little influence on the size of the indent, as long as the indent is large in comparison to the asperities of the surface [1]. It is important that the surface preparation does not alter the material properties, i.e. the surface should show a minimum of deformation after preparation.

Conversions between hardness scales should be handled with care. It is best to avoid conversions if possible and perform the hardness tests by the method required. The same goes for conversions from hardness measurements to material strength, if they are not well founded by experimental data.

DuraJet, a Rockwell hardness tester

DuraScan

Rockwell (HR)

Rockwell is a fast method, developed to be used for production control and has a direct readout. The Rockwell hardness (HR) is calculated by measuring the depth of an indent, after an indenter has been forced into the specimen material at a given load. The indenter material is a conical diamond, a sintered carbide or steel ball, depending on the scale being used. A minor preload is applied before the main load is put on and thereafter unloaded. The readout of the hardness value is performed while the minor preload is still applied, see Figure 8.

There are two types of Rockwell tests: regular Rockwell where the minor load is 10 kgf, the major load is 60, 100 or 150 kgf; and Superficial Rockwell, used for thinner specimens where the minor load is 3 kgf and major loads are 15, 30 or 45 kgf. Generally, the tested material should not be mounted in resin, because the Rockwell test uses the motion of the indenter to measure the hardness and not the indentation area. The influence hereof however depends on the machine used.

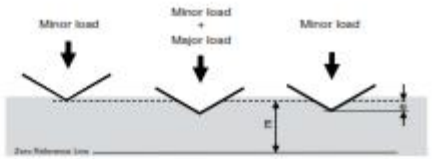


Figure 8: Schematic description of Rockwell Hardness Testing. Rockwell formula: Hardness (Rockwell HR) = E – e. "E" is a constant of 100 (diamond) or 130 (ball) units. "e" is the penetration depth in units of 0.002 mm

Brinell (HBW)

Brinell indentation gives a relatively large impression with a tungsten carbide ball, denotation HBW (W is the chemical symbol for tungsten). The size of the indent is read optically in order to determine the hardness. Typical Applications are forgings and castings where the structural elements are large and inhomogeneous or structures too coarse for other methods (Rockwell/Vickers) to give a representative result.
Load Range: 1-3000 kgf
Indenter Types: 1 / 2.5 / 5 / 10 mm diameter balls.

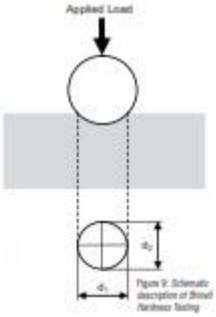
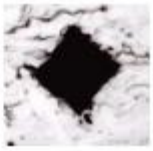


Figure 9: Schematic description of Brinell hardness Testing

Figure 13: Comparison of indent size between a) Knoop and b) Vickers indent in plasma spray coating. Load 0.5 kgf. The final polishing step was performed with the Rap cloth and diamond suspension DiaPro Rap 9 (1µm).



Vickers (HV)

The Vickers Hardness (HV) is calculated by measuring the diagonal lengths of an indent left by introducing a diamond pyramid indenter with a given load into the sample material, see Figure 10. The size of the indent is read optically in order to determine the hardness. The hardness value can be obtained from a table or formula after determining the mean value of the two measured diagonals or directly in an automatic hardness tester. The Vickers scale ranges from 10 gf to 100 kgf. For Vickers hardness testing, the obtained hardness value is relatively unaffected by the applied load.
For spacing between Vickers indents, see Figure 23.

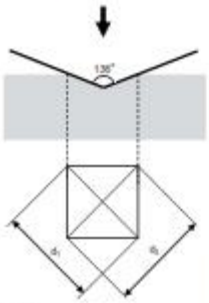


Figure 10:
Schematic description of Vickers Hardness Testing

Knoop (HK)

This method was developed as an alternative to the Vickers indenter, mainly to overcome cracking in brittle materials (such as ceramics), but also to facilitate testing of thin layers. The indenter is an asymmetrical pyramidal diamond, see Figure 11. The size of the indent is based on a measurement of only the long diagonal, which is read optically in order to determine the hardness. The load range for Knoop varies from 10 gf to 1 kgf. Knoop is more sensitive to surface preparation compared to Vickers since the longer diagonal results in a shallower indent. The spacing between indents is material dependent, see Figure 12. When using Knoop for very small loads, the hardness value increases with decreasing load.

Comparison of indent size between a Knoop and Vickers indent for the same load is found in Figure 13.

For Brinell, Vickers and Knoop it is important that the diagonal lengths are at least 20 µm or larger, otherwise measurement inaccuracy will be too high.

Microhardness testing

For micro hardness testing the test loads are, as mentioned before, less than 1 kgf and results in very small indentations. Micro hardness extends the hardness testing to materials too thin or too small for macro indentation tests, the load range being 1 gf–1000 gf, as specific

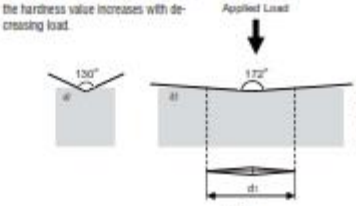


Figure 11: Schematic description of Knoop Hardness Test
a) side view
b) front view

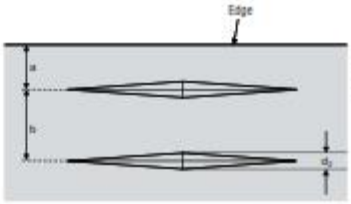


Figure 12: The indentation spacing of Knoop is based on the short diagonal d_2. a and b are explained in the below table (ISO 4545).

	a	b
Steel, copper and copper alloys	$3 \cdot d_2$	$4 \cdot d_2$
Light metals, Pb, Sn and their alloys	$3.5 \cdot d_2$	$7 \cdot d_2$

phases or constituents and regions or large hardness gradients are tested. Examples are very thin layers, small components, coatings, micro-welds, powder metal particles, individual structural elements or grains.

It is better not to etch before hardness testing because the surface will become less reflective resulting in an indent on which it is more difficult to see the corners. However, a light etch will help to discriminate between different phases/structure elements when hardness measurements are performed on individual constituents.

Also the lower the loads used during hardness testing, the higher the requirements to surface preparation that can be performed mechanically, chemically or electrochemically. It is important that no change of surface properties is induced to the specimen during preparation due to heating or cold working. Deformations introduced during cutting and grinding need to be removed by polishing down to 6, 3 or 1 µm depending on the test load. For very small loads, less than 300 gf [4], the surface needs to be completely free of deformations, and the specimens require oxide polishing or even electrolytic polishing to obtain a completely damage-free surface. One should also take into account that soft or/and ductile materials (i.e. for HV less than 120-150) are more sensitive when it comes to introducing preparation artefacts.

It is important to have a plane test surface to get reliable results, placing the specimen in a fixture will ensure that the indenter is perpendicular to the test surface.

4. Preparation recommendations

Cutting

Cutting should introduce as little deformation as possible to the specimen. Therefore it is important to select a proper combination of cut-off wheel and feed speed for the material in question, to prevent burning of the material and to ensure as short a preparation time as possible in the following steps.

Mounting

Tests[1] show that there is no significant influence of resins, see Figure 14, for test loads up to at least 30 kgf (Vickers). (Tests were performed with two hot mounting resins DuroFast (epoxy with mineral filler) and MultiFast (phenolic mounting media with wood flour filler) and one cold mounting resin, ClaroCit (acrylic resin).
If edge-retention is needed as for thin coatings or surface treated steels, a resin with filler should be used. For hardened steel, DuroFast is appropriate. For softer materials/coatings (less than 400HV) LevoFast (melamine with mineral and glass filler) is suitable.

[1]Tests were performed with 0.5% carbon steel and hardened tool steel, the diameters of the mounted steel specimen were 25 and 32 mm in diameter respectively. All mounts were 40 mm in diameter. Each column in Figure 14 represents 3 series of 12 indents except for ClaroCit where only one test series was performed.

Grinding and polishing

The grinding and polishing method depends on the material to be tested. For ferrous metals, a common method is presented in Table 2. It is suitable for most steel grades/heat treatments, for example case hardened steel. The final polishing is performed with 3 µm diamond suspension. It is a fast method which gives a reflective surface suitable for hardness testing. For softer aluminium, the method in Table 3 is recommended. Figure 15 shows automatic evaluation of hardness of 99,95% aluminium after cutting as well as after different steps of mechanical preparation. For preparation of different materials, see e-Metalog (www.struers.com). The data in Table 2 and Table 3 are valid for 6 mounted samples, 30 mm in diameter, clamped in a holder.

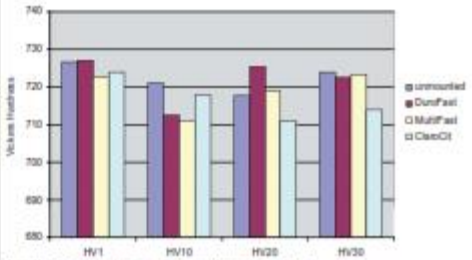


Figure 14: Results from tests investigating the influence of resins on hardness testing. Here, the specimens were placed directly on an anvil during the test. The material was hardened tool steel. Final polishing step was carried out on a MD-Plus cloth with diamond suspension DiaPro Plus (3µm).

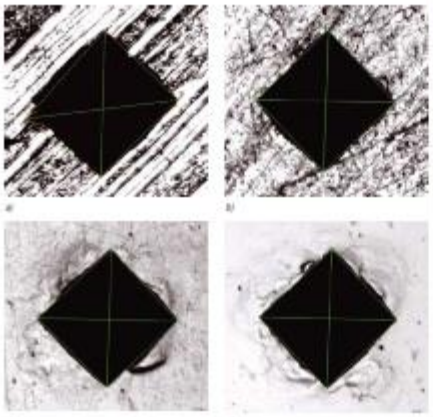
Step	PG	PG 1	P 1
Surface	MD-Piano 220	MD-Allegro	MD-Plus
Abrasive type		DiaPro Allegro/Largo	DiaPro Plus
Lubricant type	Water		
Speed [rpm]	300	150	150
Force [N]	240	240	30
Holder direction	>>	>>	>>
Time [min]	1	3	3

Table 2: Preparation method for steel. Valid for six mounted specimens 30 mm in diameter.

Step	PG	PG 1	P 1	OP
Surface	SiC-Paper #320	MD-Largo	MD-Mol	MD-Chem
Abrasive type		DiaPro Allegro/Largo	DiaPro Mol	OP-U 0.04 µm
Lubricant type	Water			
Speed [rpm]	300	150	150	150
Force [N]	120	180	150	80
Holder direction	>>	>>	>>	><
Time [min]	1	4	3	2

Table 3: Preparation method for soft aluminium. Valid for 6 mounted specimens, 30 mm in diameter.

When using very fine polished surfaces i.e. oxide polishing, it should be noted that OP-U results in less relief than OP-S.



a) b) c) d)

Figure 15: Vickers hardness testing, HV1 of 99.85% aluminium a) directly after cutting b) after fine grinding with MD-Largo and diamond suspension DiaPro Allegro/Largo (9 µm) c) after polishing with MD-Mol and DiaPro Mol (3 µm) d) after oxide polishing with MD-Chem and OP-U (colloidal silica 0.04 µm)

5. Applications

Case hardness depth

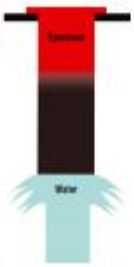
To increase wear resistance, steels are surface-hardened for applications in moving and rotating parts such as gears, nozzles, engine parts, etc.
A quantitative measure of the change in hardness can be obtained by a hardness transverse.
Case hardness depth (CHD) measurements are used in order to determine the thickness of the hardened surface layer of steel. The procedures are standardised and evaluation of the case depth depends on the method used during the surface hardening, for example if it is induction hardened, carburized or nitrided, etc.
In most cases Vickers hardness tests are used in the micro hardness load range. (In certain cases Knoop can be used).

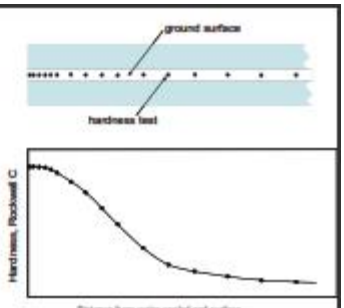
Edge-retention is needed when measuring thin coatings or heat treated surfaces. When performing a CHD, the size

Figure 16: Case depth measurement. The increasing size of the indentations towards the centre of specimen indicates decreasing hardness of the material.

Figure 17: Indents forming a zig-zag pattern

Figure 18: *Schematic description of Jominy Test (For example Jominy Number: J15 = 35 HRC means that the hardness 35 HRC is measured at a distance of 15 mm from the water cooled end)*





of the indents will increase as the hardness decreases, see Figure 16. In order to keep the minimum allowed distance between indents (for steel 3x diagonal), automatic indent spacing can be used. As the indent size increases, the distance between the indents will also increase.

Traditionally, a large number of indents needs to be performed in order to reach the hardness limit. However, it is possible with modern automatic hardness testers to stop automatically when the defined hardness number is reached, regardless of the number of test points which have been set.

There is a minimum indent spacing, since the indents should not influence each other. In order to increase the number of indents and the accuracy in test series, the indents can be displaced in relation to each other, forming a zig-zag pattern, see Figure 17.

Jominy Testing

With the Jominy test, the hardenability of a steel is tested. A test bar with specific geometry is heated up to an austenitising temperature, thereafter the end is cooled down using a standardised water jet, see Figure 18. After cooling, one side of the bar is ground and the hardness is measured (HV 30 or HRC) at intervals from the quenched end, see Figure 19. Depending on the cooling rate (distance from the water cooled end) there will be differences in the measured hardness.

Figure 19: *Jominy testing*

Welding

Hardness testing of welds typically implies that a series of indents have to be performed across a relatively large specimen surface, closely related to the geometry of the specimen. An overview camera allows the entire specimen surface to be seen and easily displays the positions where the indents should be performed. Welding standards prescribe the use of HV 5 or HV 10.

An example of location of hardness test indentations for the validation of a weld are shown in Figure 20. Table 4 shows

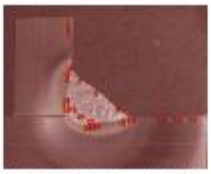


Figure 20: *Placing of test points on weld with the help of an overview camera.*

Number	Hardness	Method
1	175	HV 10
2	175	HV 10
3	177	HV 10
4	237	HV 10
5	239	HV 10
6	249	HV 10
7	230	HV 10
8	225	HV 10
9	225	HV 10
10	234	HV 10
11	236	HV 10
12	251	HV 10
13	182	HV 10
14	175	HV 10
15	178	HV 10
16	241	HV 10
17	259	HV 10
18	232	HV 10
19	221	HV 10
20	226	HV 10
21	221	HV 10
22	230	HV 10
23	230	HV 10
24	225	HV 10

Table 4: *Test results for weld*

the corresponding hardness values from Duramin A-300. Two 12 mm thick plates in carbon steel, type S55C were welded together. Before the hardness test the test surface is polished down to 6 µm and thereafter slightly etched using Nital before testing. The test is performed to validate the welding process (according to NF EN ISO15614). The maximum hardness limit for this weld was 320 HV 10.

For preparation of welds, see the Application Note on the subject.

Applied Load	Indentation	Indenter	Others
Accuracy	Speed	Lateral movement	Anvil, Support table
Repeatability	Inertia	Shape deviations	Spindle
	Angle	Damage	Deflection of sample
	Time	Material	Levelling of machine
	Spacing		

Table 5: Instrument factors

6. Controlling Parameters

Hardness tests are considered to be rather simple to perform when all parameters are controlled. For this reason it is advisable to have a basic knowledge of the subject. Below follows a brief overview of parameters influencing the hardness test.

The different parameters can be divided into five main factors influencing the hardness testing and they are related to instrument, measurement, material, operator and environment, see Figure 21. It is important to continuously seek to eliminate, minimize or at least take into account the influence of these factors, which will be mentioned/discussed in the following:

Operator factors

The operator should have an understanding of the proper operation of the hardness testing equipment, surface requirements and fixture techniques in order to use the machine as effectively as possible and thus minimize the work needed during testing.

Environment factors

The hardness test should be performed on a smooth clean reflective surface (valid for Vickers, Brinell and Knoop). It is important to perform the tests under constant conditions like temperature and humidity. For indenters with optical reading, it is necessary to take into account that the illumination influences the interpretation of the indent size. Therefore, the hardness tester should preferably be placed in a dark environment to keep the illumination constant. Vibrations from the surroundings will affect the measurement and should be minimized. Smaller loads are more sensitive to vibrations. For this reason, it is advisable to place the hardness tester on a special foundation (e.g. granite table).

The surfaces should be free from any kind of contamination such as scale, dirt, oil and grease. A thin lubricating film will lower the coefficient of friction resulting in larger indents for a given load, that is to say one will experience slight decrease in hardness. Here, it is important to keep the same condition of surfaces for all measurements to get comparable results.

Instrument factors

For the instrument factors, the load, the indentation and the indenter are considered. To obtain the necessary accuracy and repeatability of the applied load, a load cell technology is preferred since it is more accurate than systems with mechanical weights, i.e. free from influences of friction and inertia within the system. To fulfil the requirement of accuracy of the applied load, it is also important to calibrate the system regularly. In the daily routine, this is mostly an indirect verification, using calibration blocks which are available for different hardness levels, making it possible to verify the calibration in the used hardness range. The parameters affecting the indentation can be found in Table 5. The angle of indentation should not devide from the perpendicular line more than 2 degrees (maximum), otherwise errors are introduced. Also, there should be no lateral movement between indenter and specimen. If possible, the specimen should be clamped on a burr-free anvil.

Spacing between indents should be large enough for the indents not to influence each other. The plastic deformation around an indent will cause most materials to harden, therefore if the indents are too close, the material will appear to be harder. The principle for the development of the plastic zone (blue area) for a flat punch (yellow) is shown in Figure 22.

For this reason, the standards for the different tests give specifications for the spacing between indents and the spacing towards the edge, for Vickers hardness testing, the instruction given by ISO can be seen in Figure 23.

Figure 21: Five main factors influencing the hardness testing

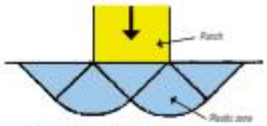
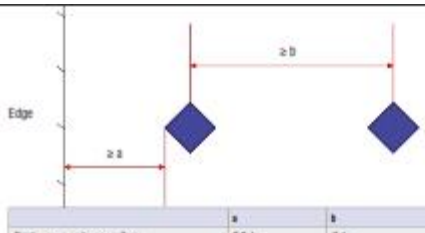


Figure 22: Slip-line field of plastic zone (blue area) development from indent of a rigid flat punch (yellow) according to Prandtl



	a	b
Steel, copper and copper alloys	$2.5 \cdot d_m$	$3 \cdot d_m$
Light metals, Pb, Sn and their alloys	$3 \cdot d_m$	$8 \cdot d_m$

Figure 23: Spacing between Vickers indents according to ISO 6507. a and b are explained in the table below, where d_m is the mean diagonal of an indent.

Material factors

The material factors are:

- Heterogeneity of microstructure
- Quality of specimen preparation
- Reflectivity/Transparency of specimen surface
- Type of material
- Material treatment
- Shape of material
- Mounting resin

An appropriate specimen thickness is needed; the indent should not penetrate through the entire specimen. It is important that there is no visible deformation present at the back of the test piece after the hardness test.
For this reason, the specimen thickness should be at least 10 times the indentation depth (Rockwell). For Vickers it has to be at least 1.5 times the diagonal length of the indentation.

Corrections need to be performed when measuring on spherical and cylindrical surfaces. The correction factor will depend on the surface being concave or convex. These correction factors can be found manually in tables or they are incorporated in newer automatic hardness testers. For round specimens, also special anvils should be used (se Figure 24) and correction factors for convex surfaces.

When choosing a suitable type of hardness test, it is important that the indent area covers all different structural elements present in the tested material in order to obtain an indentation that represents the whole structure of the material. For example, for a cast structure, hardness testing is preferably performed with Brinell, since this type of structure is rather inhomogeneous and therefore a larger indent is needed to cover the different structural elements.

Procedure used	Verification System	Others
Applied method (HV, HB, HR, HK)	Calibration of loading systems	Vibrations
Feasibility of method	Magnification of objective lenses	Dirt, dust, debris
Standard to be followed (ASTM/ISO, JIS)	Resolution of objective lenses	
	Inadequate image quality	
	Uniformity of illumination	

Table 6: Measurement Factors

Measurement factors

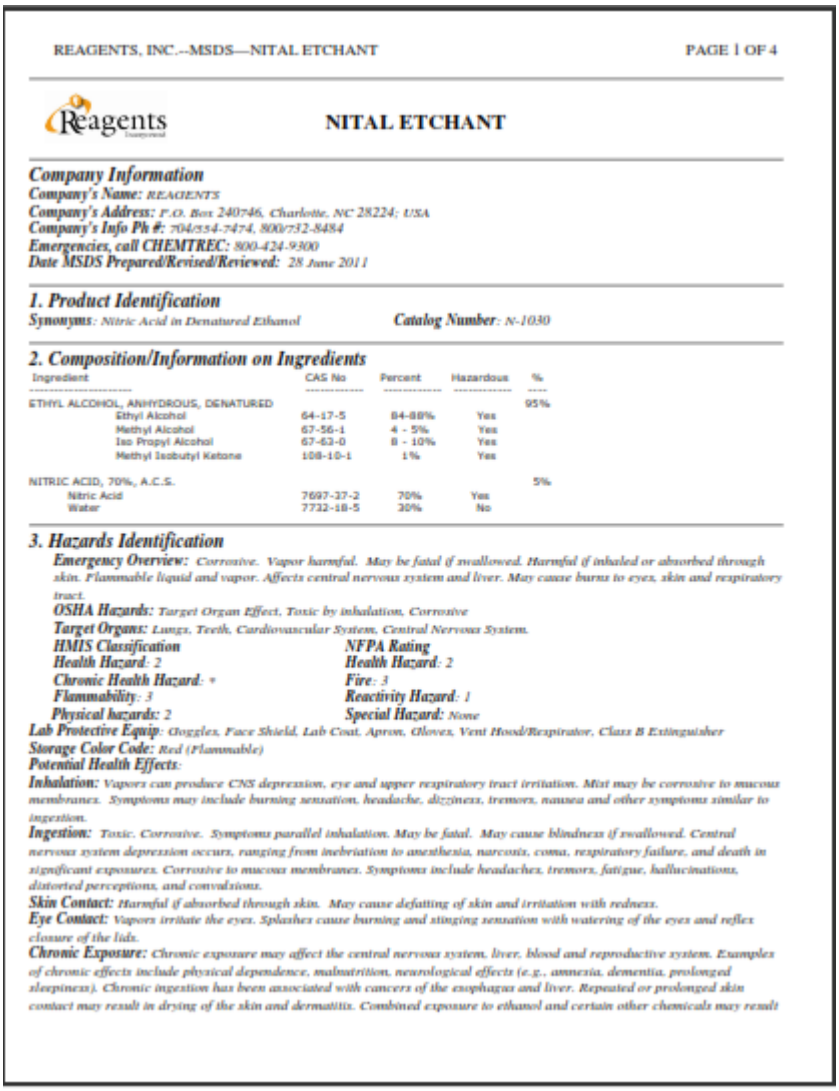
The measurement factors are found in Table 6. If a hardness tester is used for performing several different hardness tests, it is necessary to verify each test separately. Before verification takes place, it should be checked that the illumination does not affect the readings.

For hardness testers based on optical readings, as high loads as possible should be used to minimize errors. The diagonal/diameter length of the indentation should be larger than 20 µm. For Vickers, the difference in diagonal length for the same indent should be less than ±5%. For optimal results, when possible, the diagonal should be between 25-75% of the field of view of the lens. When determining large hardness gradients, for example for case hardening, this requirement can be difficult to fulfil.

It is important that the indenter is free from faults/surface defects in order to get reliable results. It can preferably be checked on a daily basis by visual inspection of an indentation in a reference block, to ensure there are no flaws, cracks etc. on the indenter surface (Vickers ISO 6507). As soon as a defect is present on the indenter, no reliable results can be obtained.

Figure 24: Special anvil for cylindrical surface

Appendix 2. Material Safety Data Sheet (MSDS) for Nital



REAGENTS, INC.--MSDS—NITAL ETCHANT PAGE 1 OF 4

Reagents

NITAL ETCHANT

Company Information

Company's Name: *REAGENTS*
Company's Address: *P.O. Box 240746, Charlotte, NC 28224; USA*
Company's Info Ph #: *704/554-7474, 800/732-8484*
Emergencies, call CHEMTREC: *800-424-9300*
Date MSDS Prepared/Revised/Reviewed: *28 June 2011*

1. Product Identification

Synonyms: *Nitric Acid in Denatured Ethanol* **Catalog Number:** *N-1030*

2. Composition/Information on Ingredients

Ingredient	CAS No	Percent	Hazardous	%
ETHYL ALCOHOL, ANHYDROUS, DENATURED				95%
Ethyl Alcohol	64-17-5	84-88%	Yes	
Methyl Alcohol	67-56-1	4 - 5%	Yes	
Iso Propyl Alcohol	67-63-0	8 - 10%	Yes	
Methyl Isobutyl Ketone	108-10-1	1%	Yes	
NITRIC ACID, 70%, A.C.S.				5%
Nitric Acid	7697-37-2	70%	Yes	
Water	7732-18-5	30%	No	

3. Hazards Identification

Emergency Overview: *Corrosive. Vapor harmful. May be fatal if swallowed. Harmful if inhaled or absorbed through skin. Flammable liquid and vapor. Affects central nervous system and liver. May cause burns to eyes, skin and respiratory tract.*

OSHA Hazards: *Target Organ Effect, Toxic by inhalation, Corrosive*

Target Organs: *Lungs, Teeth, Cardiovascular System, Central Nervous System.*

HMIS Classification
Health Hazard: *2*
Chronic Health Hazard: ***
Flammability: *3*
Physical hazards: *2*

NFPA Rating
Health Hazard: *2*
Fire: *3*
Reactivity Hazard: *1*
Special Hazard: *None*

Lab Protective Equip: *Goggles, Face Shield, Lab Coat, Apron, Gloves, Vent Hood/Respirator, Class B Extinguisher*
Storage Color Code: *Red (Flammable)*
Potential Health Effects:

Inhalation: *Vapors can produce CNS depression, eye and upper respiratory tract irritation. Mist may be corrosive to mucous membranes. Symptoms may include burning sensation, headache, dizziness, tremors, nausea and other symptoms similar to ingestion.*

Ingestion: *Toxic. Corrosive. Symptoms parallel inhalation. May be fatal. May cause blindness if swallowed. Central nervous system depression occurs, ranging from inebriation to anesthesia, narcosis, coma, respiratory failure, and death in significant exposures. Corrosive to mucous membranes. Symptoms include headaches, tremors, fatigue, hallucinations, distorted perceptions, and convulsions.*

Skin Contact: *Harmful if absorbed through skin. May cause defatting of skin and irritation with redness.*

Eye Contact: *Vapors irritate the eyes. Splashes cause burning and stinging sensation with watering of the eyes and reflex closure of the lids.*

Chronic Exposure: *Chronic exposure may affect the central nervous system, liver, blood and reproductive system. Examples of chronic effects include physical dependence, malnutrition, neurological effects (e.g., amnesia, dementia, prolonged sleepiness). Chronic ingestion has been associated with cancers of the esophagus and liver. Repeated or prolonged skin contact may result in drying of the skin and dermatitis. Combined exposure to ethanol and certain other chemicals may result*

in increased toxic effects. Prolonged exposure may affect the kidneys.

Aggravation of Pre-existing Conditions: *Persons with pre-existing skin disorders, eye problems, liver disease, central nervous system disorders, or impaired respiratory function may be more susceptible to the effects of the substance.*

4. First Aid Measures

Inhalation: *Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.*

Ingestion: *Give 2-3 glasses of water to dilute. Do not induce vomiting. Never give anything by mouth to an unconscious person. Get medical attention immediately.*

Skin Contact: *Immediately flush skin with plenty of water for at least 15 minutes. Remove contaminated clothing and shoes. Get medical attention. Wash clothing before reuse. Destroy contaminated shoes.*

Eye Contact: *Immediately flush eyes with plenty of water for at least 15 minutes, lifting lower and upper eyelids occasionally. Get medical attention immediately.*

5. Fire Fighting Measures

Fire: Flash point (TCC): *16.1C (61F)* ***Autoignition temperature:*** *No information available for mixture.*

Flammable limits in air % by volume: *LEL: 3.3 Listed values are for pure ethanol. Flammable Liquid and Vapor!*

Explosion: *Sealed containers may rupture when heated. Above the flash point, explosive vapor-air mixtures may be formed. Vapor may explode if ignited in an enclosed area. Vapors can flow along surfaces to distant ignition source and flash back.*

Fire Extinguishing Media: *Most appropriate extinguishers are carbon dioxide and alcohol-resistant foam. Use water in flooding quantities as fog. Water spray may be used to keep fire exposed containers cool. Do not allow water runoff to enter sewers or waterways.*

Special Information: *In the event of a fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full-facepiece operated in the pressure demand or other positive pressure mode.*

6. Accidental Release Measures

Ventilate area of leak or spill. Remove all sources of ignition. Wear appropriate personal protective equipment as specified in Section 8. Isolate hazard area. Keep unnecessary and unprotected personnel from entering. Contain and recover liquid when possible. Use non-sparking tools and equipment. Collect liquid in an appropriate container or absorb with an inert material (e. g., vermiculite, dry sand, earth), and place in a chemical waste container. Do not use combustible materials, such as saw dust. Do not flush to sewer! If a leak or spill has not ignited, use water spray to disperse the vapors, to protect personnel attempting to stop leak, and to flush spills away from exposures.

7. Handling and Storage

Protect against physical damage. Store in a cool, dry well-ventilated location, away from any area where the fire hazard may be acute. Outside or detached storage is preferred. Separate from incompatibles. Containers should be bonded and grounded for transfers to avoid static sparks. Storage and use areas should be No Smoking areas. Use non-sparking type tools and equipment, including explosion proof ventilation. Containers of this material may be hazardous when empty since they retain product residues (vapors, liquid); observe all warnings and precautions listed for the product. Do not attempt to clean empty containers since residue is difficult to remove. Do not pressurize, cut, weld, braze, solder, drill, grind or expose such containers to heat, sparks, flame, static electricity or other sources of ignition: they may explode and cause injury or death.

8. Exposure Controls/Personal Protection

Airborne Exposure Limits:

For Ethyl Alcohol: *- OSHA Permissible Exposure Limit (PEL): 1,000 ppm (TWA)*

- ACGIH Threshold Limit Value (TLV): 1,000 ppm (TWA), A4 (Not Classifiable as a Human Carcinogen)

For Methyl Alcohol: *- OSHA Permissible Exposure Limit (PEL): 200 ppm (TWA)*

- ACGIH Threshold Limit Value (TLV): 200 ppm (TWA), 250 ppm (STEL) skin

For Methyl Isobutyl Ketone: *-OSHA Permissible Exposure Limit (STEL): 75 ppm (TLV) TWA 50 ppm*

-ACGIH Threshold Limit Value (TLV STEL): 75 ppm

For Nitric Acid: *-OSHA Permissible Exposure Limit (PEL): 2 ppm (TWA), 4 ppm (STEL)*

-ACGIH Threshold Limit Value (TLV): 2 ppm (TWA); 4 ppm (STEL)

For Isopropanol: *-OSHA Permissible Exposure Limit (PEL): 400 ppm (TWA)*
-ACGIH Threshold Limit Value (TLV): 200 ppm (TWA), 400 ppm (STEL), A4 - not classifiable as a human carcinogen.
Ventilation System: *A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits.*
Personal Respirators (NIOSH-Approved): *If the exposure limit is exceeded, wear a supplied air, full-face piece respirator, air-lined hood, or full-face piece self-contained breathing apparatus.*
Skin Protection: *Wear impervious protective clothing, including boots, gloves, lab coat, apron or coveralls, as appropriate, to prevent skin contact.*
Eye Protection: *Use chemical safety goggles and/or a full-face shield where splashing is possible. Maintain eye wash fountain and quick-drench facilities in work area.*

9. Physical and Chemical Properties

Appearance: *Clear, colorless liquid.*
Odor: *Mild odor.*
Solubility: *Miscible in water.*
Specific Gravity @ 60/60f (air): *Approx.0.80*
pH: *No information found.*
% Volatiles by volume: *>98.*
Boiling Point: *No information found.*
Freezing Point: *No information found.*
Vapor Density (Air=1): *No information found.*
Vapor Pressure (mm Hg): *No information found.*

10. Stability and Reactivity

Stability: *Stable under ordinary conditions of use and storage.*
Hazardous Decomposition Products: *Carbon dioxide, carbon monoxide, and formaldehyde when heated to decomposition.*
Hazardous Polymerization: *Will not occur.*
Incompatibilities: *Strong oxidizing agents. Violent reaction occurs with strong oxidizing material. Methanol may react with metallic aluminum and generate hydrogen gas. May form explosive peroxides in air.*
Conditions to Avoid: *Heat, flames, ignition sources and incompatibles.*

11. Toxicological Information

Toxicological Data: For Ethyl Alcohol: *LD_{50} oral rat 7060 mg/kg; LC_{50} inhalation rat 20,000 ppm/10H; Irritation skin rabbit, std Draize, 20 mg/24H, moderate; Irritation eye rabbit, std Draize, 500 mg/24H, mild. Investigated as a tumorigen, mutagen, reproductive effector.* **For Methyl Isobutyl Ketone:** *Oral rat LD_{50}: 2080 mg/kg; Skin rabbit > 20 mL/kg; Irritation eye rabbit, Standard Draize, 40 mg severe; investigated as a reproductive effector.* **For Methyl Alcohol (Methanol):** *Oral rat LD_{50}: 5628 mg/kg; inhalation rat LC_{50}: 64000 ppm/4H; skin rabbit LD_{50}: 15800 mg/kg; Irritation data-standard Draize test: skin, rabbit: 20mg/24 hr. Moderate; eye, rabbit: 100 mg/24 hr. Moderate. Investigated as a mutagen, reproductive effector.*
For Nitric Acid: *Inhalation rat LC_{50}: 244 ppm (NO_2)/30M: Investigated as a mutagen, reproductive effector. Oral (human) LD_{Lo}: 430 mg/kg.* **For Isopropanol:** *Oral rat LD_{50}: 5045 mg/kg; skin rabbit LD_{50}: 12.8 g/kg; Inhalation rat LC_{50}: 16,000 ppm/8-hour; investigated as a tumorigen, mutagen, reproductive effector. IARC category 3 (not classifiable as to its carcinogenicity to humans).*
Reproductive Toxicity: *Ethanol has been linked to birth defects in humans. Ethanol crosses the placenta and can cause acute intoxication of the newborn or teratogenic effects, including fetal alcohol syndrome.*

12. Ecological Information

Environmental Fate: *No information found for mixture.*
Environmental Toxicity: *No information found for mixture. This material is expected to be toxic to aquatic life.*

13. Disposal Considerations

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

14. Transport Information

Proper Shipping Name: *Flammable Liquids, Corrosive, N.O.S. (Ethanol, Nitric Acid)*
Hazard Class: *3, 8* **UN/NA:** *UN2924* **Packing Group:** *II*

15. Regulatory Information

TSCA: *All components are listed.*
SARA 302 Components: *Nitric Acid, CAS No. 7697-37-2 (RQ 1000lbs)..*
SARA 313 Components: *Methanol, CAS No. 67-56-1; Methyl isobutyl ketone, CAS No. 108-10-1; Propan-2-ol, CAS No. 67-63-0; Nitric Acid, CAS No. 7697-37-2.*
SARA 311/312 Hazards: *Fire Hazard, Acute Health Hazard, Chronic Health Hazard.*
CERCLA Hazardous Substance: *Methanol, CAS No. 67-56-1; Methyl isobutyl ketone, CAS No. 108-10-1; Nitric Acid, CAS No. 7697-37-2.*
Clean Air Act: *This material contains hazardous air pollutants: Methanol, CAS No. 67-56-1; Methyl isobutyl ketone, CAS No. 108-10-1. This material does not contain any Class 1 or Class 2 Ozone depletors.*
Clean Water Act: *This material does not contain any Priority Pollutants.*
California Prop. 65 Components: *This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm. (The ethanol is not in an alcoholic beverage.)*
DSL Status: *All components of this product are on the Canadian DSL list.*

16. Other Information

Product Use: *Laboratory Reagent.*
Disclaimer: Reagents provides the information contained herein in good faith but makes no representation as to its comprehensiveness or accuracy. This document is intended only as a guide to the appropriate precautionary handling of the material by a properly trained person using this product. Individuals receiving the information must exercise their independent judgment in determining its appropriateness for a particular purpose. REAGENTS MAKES NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE INFORMATION SET FORTH HEREIN OR THE PRODUCT TO WHICH THE INFORMATION REFERS. ACCORDINGLY, REAGENTS WILL NOT BE RESPONSIBLE FOR DAMAGES RESULTING FROM USE OF OR RELIANCE UPON THIS INFORMATION.