Workbook:

PRACTICAL OF DJJ30113

Materials Science & Engineering

SECOND EDITION

Norfidah Jaharudin | Hairul Haya Mohd Zin | Surniza Mohd Hilmin

POLITEKNIK MALAYSIA

WORKBOOK: PRACTICAL OF DJJ30113

MATERIALS SCIENCE & ENGINEERING

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ABSTRACT

All polytechnic students who take Materials Science and Engineering's subject must undergo practical tasks. Practical consists of four experiments that need to be done, namely torsion test, heat treatment, hardness test, and dye penetrant testing. After conducting an experiment, students must make observations, data analysis, the argument of the result in the discussion, and also summarize all the analysis that has been made in the conclusion. These all need to be written in the practical report for each experiment that has been conducted. This book is a lab sheet compilation for all the practical tasks that need to be done. It is also contained a report template for students to make a report after they conduct the experiment. Moreover, this workbook guide students to conduct an experiment and to write the report much easier and correctly.

PREFACE

Thanks to Allah, the Lord of the world because of his grace, we can complete a book entitled Practical of DJJ30113, Materials Science & Engineering. We wish to express our deep and sincere gratitude for those who have guided and given full cooperation and commitment in completing this book.

This book is designed primarily to supplement the standard manual in elementary for courses DJJ30113 Material Science and Engineering. Moreover, the statement and theory procedure are sufficiently complete that with suitable handling of lecture recitation time. The book could be used as a text by itself.

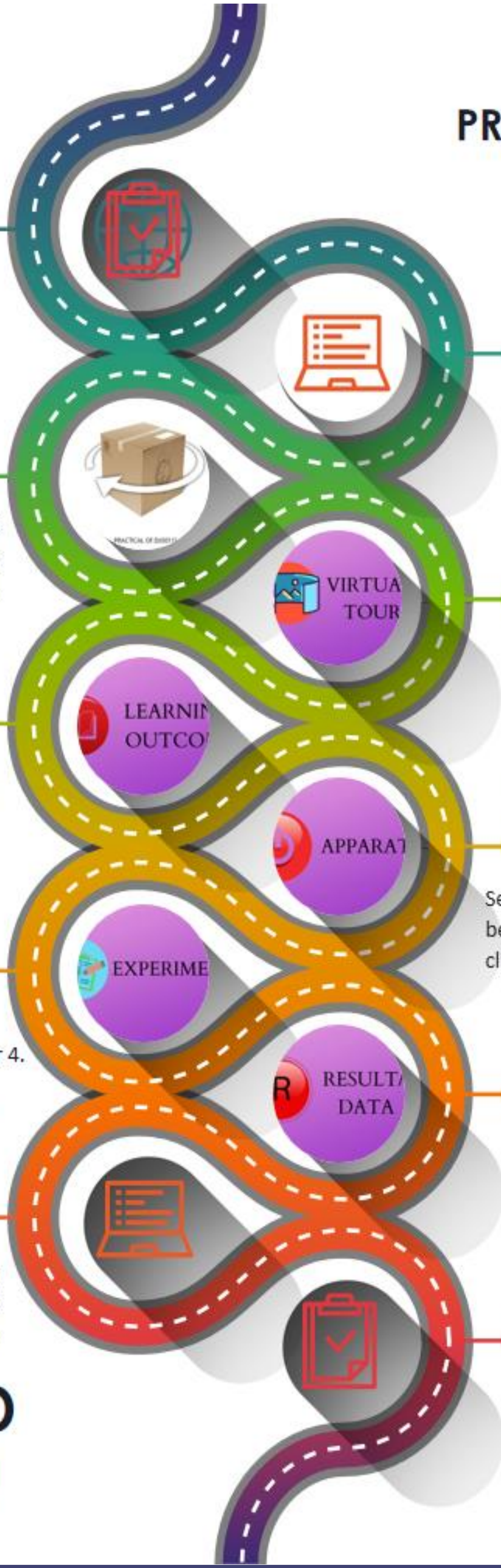
This book is present to improve the teaching and learning process for this module and also used for reference to the student semester three in Mechanical Engineering Department at Polytechnic.

By using this book, the students are exposed to the practical task of Materials Science and Engineering by performing appropriate material testing according to the Standard Operating Procedures.

Any suggestions for the improvement of the book will be thankfully acknowledged and incorporated in the next addition.

GUIDE CD LABORATORY

TIMELINE PRACTICAL OF DJJ30113



1FIRST

Do pre-test and summit.

2SECOND

Open lab sheet. Print. Prepare for the practical.

3THIRD

Open the LAB DJJ30113 folder. Then click the Practical of DJJ30113.

4FOURTH

Do the virtual tour into the lab by click the Virtual Tour icon.

5FIFTH

See the learning outcome of the practical by click the learning outcome icon.

6SIXTH

See the apparatus that has been used in this practical by clicking the apparatus icon.

7SEVENTH

Click the experiment icon to began experiment 1 or 2 or 3 or 4. Do the experiment based on sequence and refer to the lab sheet.

8EIGHTH

The Result/Data icon is for the findings for all experiments.

9NINTH

credit icon is for recognition for all involved with the production of this video.

10TENTH

Do post-test and fill in survey form. Summit.

SECOND EDITION

SYNOPSIS

MATERIALS SCIENCE AND ENGINEERING course introduces students a comprehensive coverage of basic fundamentals of materials science and engineering. The course focuses on material structures, properties, fabrication methods, corrosion, thermal processing and material testing mostly of metals and alloys. New fabrication method of powder metallurgy are introduces to student to cater the fabrications of devices, sensors for Industry 4.0 technology.

COURSE LEARNING OUTCOMES

Upon completion of this course, students should be able to:

1. Apply the fundamental of material science to identify the materials, properties, behaviour, processes and treatment. (C3, PLO1)
2. Performed appropriate material testing according to the Standard Operating Procedures. (P4, PLO5)
3. Demonstrate the ability to work individually and in groups to complete assigned tasks during the practical work session. (A3, PLO9)

APPENDIX 1: EXPERIMENT 1 TORSION TEST

POLITEKNIK MALAYSIA

MECHANICAL ENGINEERING DEPARTMENT

ACADEMIC SESSION: ____________________

DJJ30113 – MATERIAL SCIENCE AND ENGINEERING

PRACTICAL WORK	:	TORSION TESTING OF BRASS, STEEL AND ALUMINUM		
PRACTICAL WORK DATE	:			
LECTURER'S NAME	:			
GROUP NO.	:		CLASS:	

No.	STUDENT ID & NAME	TOTAL MARKS

DATE SUBMIT:	DATE RETURN:

RUBRIC

	NO	CRITERIA	EXCELLENT 5	VERY GOOD 4	GOOD 3	FAIR 2	UNSATISFACTORY 1	MARKS
CL02P	A	**Introduction**	· Very well-written, clearly explain the relevant experiment background.	· Good written, explain the relevant experiment background.	· Experiment background is nearly complete but does not provide for some minor information	· Experiment background is lack of complete with some minor information	· Very little experiment background information provided or information is incorrect	[/5]
	B	**Objective**	· Objective is clearly identified	· Objective is clearly identified	· Objective is identified.	· Objective is less identified.	· Objective is not identified.	[/5]
	C	**Safety Procedure & Equipment**	· Safety procedures are listed in clear steps. Each step is numbered and in a complete sentence. All necessary laboratory equipment included and listed in an organized manner	· Safety procedures are listed. Each step is numbered and in a complete sentence. · All necessary laboratory equipment included and listed.	· Safety procedures are listed in clear steps but not numbered and/or in complete sentences. All necessary laboratory equipment included but not listed in any particular order	· Safety procedures are less listed in and not numbered and/or in complete sentences. A few necessary laboratory equipment included and not listed in any particular order.	· Safety procedures are not listed. There is not a list of the necessary laboratory equipment	[/5]
	D	**Methods**	· Narrative and details methods/procedural explanation	· Methods/procedural explanation are stated but not in passive work.	· Narrative missing some methods details or observations or includes insignificant procedural details	· Narrative missing nearly overall methods details or observations or not includes insignificant procedural details	· Not written in narrative form. Procedural/methods steps are incorrect	[/5]
	E	**OBSERVATION & ANALYSIS**	There has a detail observation of the result. All figure, table and graph are correctly down, are numbered and in a complete sentence.	The data was observed with example calculation. All figure, table and graph are correctly down.	All figure, table and graph are correctly down, but some have minor problems or could still be improved.	There has an observation of the result but many incorrect data.	Figures and tables contain errors or are poorly constructed, have missing titles, captions or numbers, units missing or incorrect.	[/5]
	F	**ARGUMENT OF THE RESULT**	· Results have been interpreted correctly and discussed, good understanding of results is conveyed. Student clearly makes connections between practical work and theory	· Results have been interpreted correctly and discussed, good understanding of results is conveyed. Student less makes connections between practical work and theory	· Some of the results have been correctly interpreted and discussed. Student fails to make one or two connections to underlying theory.	· Some of the results have been correctly interpreted and discussed. Student fails to make one or two connections to underlying theory.	· "explains away" results with incorrect explanation.	[/5]
	G	**Conclusion**	· Accurate statement of the results of experiment indicates whether results support objectives.	· Less accurate statement of the results of experiment indicates whether results support objectives.	· A statement of the results of the experiment indicates whether results support the objectives	· A statement of the results of the experiment indicates but results did not support the objectives	· No conclusion was included or shows little effort and reflection on the experiment.	[/5]
	H	**References**	· All sources (information and graphics) are accurately documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are accurately documented. Some are primary scholarly sources but two or more are not. References are not directly cited in text.	· Less sources (information and graphics) are accurately documented. No primary scholarly sources. References are not directly cited in text.	· Sources are not documented or information is plagiarized from sources.	[/5]
							TOTAL MARKS	[/40]
							PERCENTAGES (/40) X 20 MARKS	[/20]

1 **LEARNING OUTCOMES (LO)**

Performed appropriate material testing according to the Standard Operating Procedures. (P4, PLO5)

2 **OBJECTIVE**

At the end of the lab session students should be able:

i. Learn the basics of torsion theory.

ii. Learn and practices the principle of torsion testing

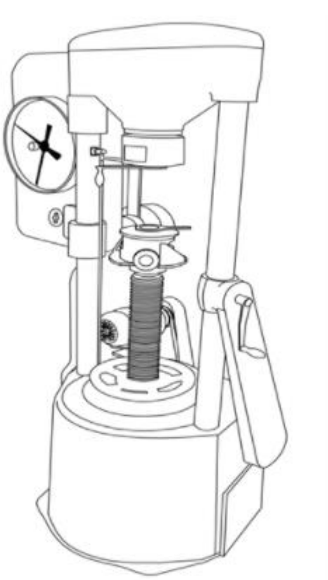
iii. Understand the differences between material properties of different material.

iv. Able to select material for different engineering components which are under torsion.

3 **THEORY**

The round bar is put in the machine so that its longitudinal axis coincides with the axis of the grips and it remains straight during the test in torsion testing. Then rotate one grip at a tolerable steady speed until the test piece breaks; shearing stresses will form in any cross section of the bar whose value increases linearly from zero in the centre to a maximum at the periphery. The twist is measured using a troptometer with a one-minute precision.

The torsion test is used to determine the value of a metallic specimen's modulus of rigidity and ultimate shear strength. A schematic diagram of a torsion testing machine is shown in Figure 1.



g Machine

(Source: https://sm-nitk.vlabs.ac.in/exp19/index.htm)

Reason perform a torsion test:

i. Many products and components are subjected to torsional forces during their operation.
ii. Torsion testing is necessary when engineers wish to change or update the materials used in these products.
iii. Torsional testing can help the engineer identify an appropriate material that will possess the required torsional strength while also contributing to the goal of light weighting.

During their functioning, many finished items are also subjected to torsional forces. Biomedical tubing, switches, and fasteners are just a few examples of products that are subjected to torsional loads in ordinary use. Manufacturers may imitate real-world service circumstances, assess product quality, verify designs, and assure proper production procedures by testing their items in torsion.

Types of torsion testing vary from product to product but can usually be classified as:

i. Axial-Torsion: Applying both axial (tension or compression) and torsional forces to the test specimen.
ii. Torsion Only: Applying only torsional loads to the test specimen
iii. Failure Testing: Twisting the product, component, or specimen until failure. Failure can be classified as either a physical break or a kink/defect in the specimen.
iv. Proof Testing: Applying a torsional load and holding this torque load for a fixed amount of time.

Failure patterns in torsion test is shown in Figure 2 below.

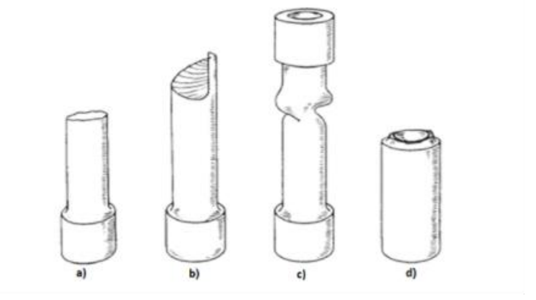


Figure 2 Failure patterns in torsion test
(Source: http://up.persianscript.ir/uploads/13452737931.pdf)

a. Solid ductile metal bars (mild steel): Ductile torsion failure reveals a flat, transverse break having smooth shear surface and microvoid formation. The failure occurs along a plane perpendicular to the axis, in this plane the principal stress will be maximum.

b. Solid brittle metal bars: The crack propagates on a helical plane. The fracture surface roughness increases with distance of propagation, crack propagation rate, and decreased strength level. 45-degree helicoidal fracture will take place.

c. Ductile metal tube-failure by buckling.

d. Brittle metal tube

4 **EQUIPMENT / TOOLS**

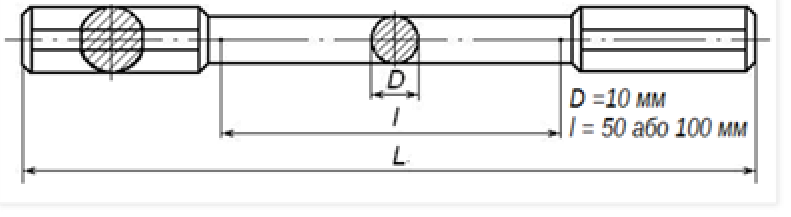
i. Torsion testing machine

ii. Troptometer

iii. Micrometer

iv. Rod / test specimen (gauge)

v. Scale

5	**SAFETY PRECAUTIONS** i. Perform only those practical tasks authorized by your instructor. Carefully follow all instructions, both written and oral. Unauthorised practical tasks are not allowed. ii. Be prepared for your work in the workshop. Read all procedures thoroughly before entering the workshop. Never fool around in the workshop. iii. Always work in a well-ventilated area. iv. Observe good housekeeping practices. Work areas should be kept clean and tidy at all times.
6	**PROCEDURE** i. Measure the specimen initial length, initial diameter and initial gauge length and put these values on the provided table.  Figure 3 Specimen i. Mark a line along the length of specimen with the help of permanent pen. This will help to measure the rotation during twisting. ii. Calibrate the torsion testing equipment as explained above. iii. Use the hexagonal sockets to grip specimen on torsion testing machine. iv. Fix one end of specimen on input and other end on torque shaft and apply small preload. v. Set torque meter to zero. vi. Start the process and twist the specimen with the strain increment of 0.5 degree until failure of specimen. vii. Record all experimental data in the provided table. Note: before taking reading make sure that it's not fluctuating and leveled off.

7	**RESULT/DATA**

Record all experimental data in the provided table below.

Table 1.1 : Specimen dimensions

Dimensions	Brass	Steel	Aluminum
Diameter (mm)			
Length (mm)			

Table 1.2: Angular displacement and torque

From	To	Increment

Table 1.3: Experimental results

Angular Deflection		Torque Transmitted (Nm)		
Degree	Radian	Brass	Steel	Aluminum

Plot Graph of torque against angular displacement (ϴ Radian) for brass, steel and aluminum.

8	**SAMPLE CALCULATION :**

Calculating polar moment of inertia

$$J= (\pi \times D^4)/32$$

$$J= (\pi \times 6^4)/32$$

Calculating Modulus of Rigidity

$$G= T/\theta \times l/J$$

Calculating shear Stresses

$$\tau/r= G\theta/l$$

$$\tau/r= T/J$$

9	**DISCUSSION** i. What do you mean by modulus of rigidity? ii. What are the different failure modes of the specimens? iii. State the factor of alteration of result.
10	**CONCLUSION AND RECOMMENDATION** Compare the results of the Modulus of rigidity between brass, steel and aluminum based on graph in result.
11	**REFERENCES**

APPENDIX 2: EXPERIMENT 2 HEAT TREATMENT

POLITEKNIK MALAYSIA

MECHANICAL ENGINEERING DEPARTMENT

ACADEMIC SESSION: ____________________

DJJ30113 – MATERIAL SCIENCE AND ENGINEERING

PRACTICAL WORK	:	HEAT TREATMENT		
PRACTICAL WORK DATE	:			
LECTURER'S NAME	:			
GROUP NO.	:		CLASS:	

No.	STUDENT ID & NAME	TOTAL MARKS

DATE SUBMIT:	DATE RETURN:

RUBRIC

	NO	CRITERIA	EXCELLENT 5	VERY GOOD 4	GOOD 3	FAIR 2	UNSATISFACTORY 1	MARKS
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	H	References	· All sources (information and graphics) are accurately documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are accurately documented. Some are primary scholarly sources but two or more are not. References are not directly cited in text.	· Less sources (information and graphics) are accurately documented. No primary scholarly sources. References are not directly cited in text.	· Sources are not documented or information is plagiarized from sources.	[/5]
							TOTAL MARKS	[/40]
							PERCENTAGES (/45) X 20 MARKS	[/20]

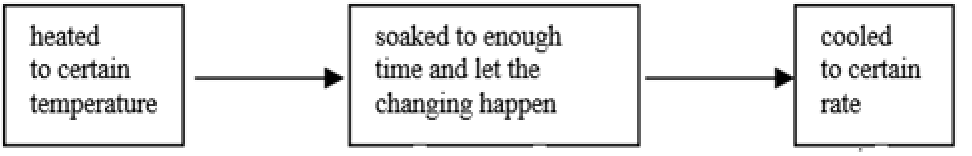
1	**LEARNING OUTCOMES (LO)** Performed appropriate material testing according to the Standard Operating Procedures. (P4, PLO5)
2	**OBJECTIVE** At the end of the lab session students should be able to: i) perform the following heat treatment processes on low carbon steel. a. Annealing b. Normalizing c. Quenching ii) Report the outcomes of the heat treatment of steels
3	**THEORY** Heat treatment is defined as an operation or combination of operations, involving heating and cooling of a metal or alloy in its solid state with the object of changing the characteristics of the material. Heat treatment is generally employed for following purposes: i. To improve machinability. ii. To change or refine grain size. iii. To relieve the stresses of the metal induced during cold or hot working. iv. To improve mechanical properties e.g. tensile strength, hardness, ductility, shock resistance to corrosion etc. v. To improve mechanical and electrical properties. vi. To increase resistance to wear, heat and corrosion. vii. To produce a hard surface on a ductile interior. Three stages in heat treatment cycle: i. Heating: heat slowly until the set temperature is dependent on carbon content. ii. Soaking: soaked or left at that temperature in a certain period depending on the size of the heat-treated components. iii. Cooling: cooled in the media designated by proportion.

Three stages in heat treatment cycle:

i. Heating: heat slowly until the set temperature is dependent on carbon content.

ii. Soaking: soaked or left at that temperature in a certain period depending on the size of the heat-treated components.

iii. Cooling: cooled in the media designated by proportion.



Heat treatment techniques include:

i. Annealing

ii. Normalizing

iii. Quenching

iv. case hardening

v. tempering

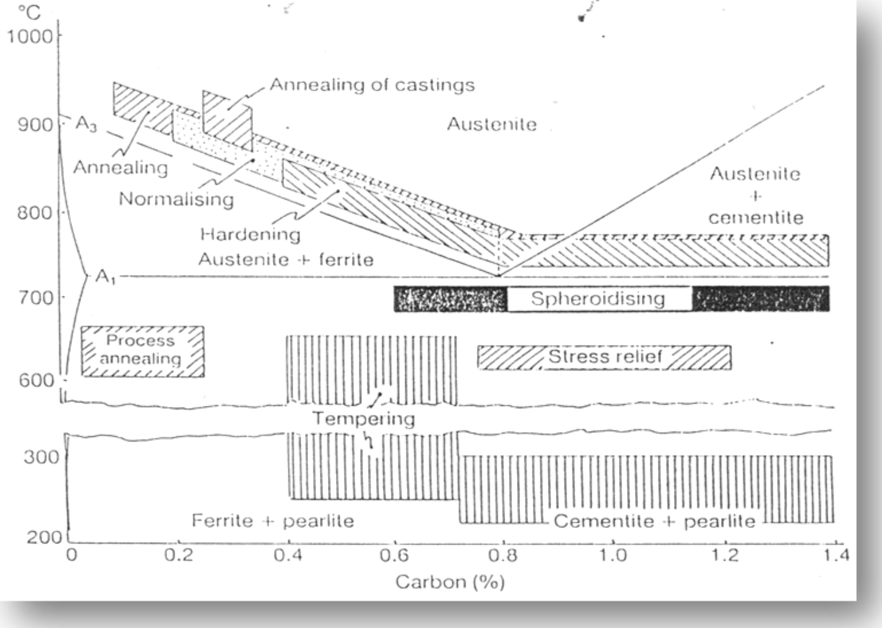


Figure 2.1 : Heat treatment for steel phase diagram

The ability to comprehend the Fe-C phase diagram presented in Figure 2.1 is based on understanding heat treatment of steels. Eutectoid steel has a C content of 0.76 percent by weight. Steel with a carbon percentage of less than 0.76 wt% C is hypoeutectoid, while steel with a carbon content of more than 0.76 wt% C is hypereutectoid. Austenite has a face-centered-cubic (FCC) region, while ferrite has a body-centered-cubic (BCC) zone (BCC).

There are also regions that have two phases. If one cools a hypoeutectoid steel from a point in the austenite region, reaching the A_3 line, ferrite will form from the austenite. This ferrite is called proeutectoid ferrite. When A_1 is reached, a mixture of ferrite and iron carbide (cementite) forms from the remaining austenite. The microstructure of a hypoeutectoid steel upon cooling would contain proeutectoid ferrite plus pearlite (α+ Fe_3C).

The size, type and distribution of phases present can be altered by not waiting for thermodynamic equilibrium. Steels are often cooled so rapidly that metastable phases appear. One such phase is martensite, which is a body-centered tetragonal (BCT) phase and forms only by very rapid cooling.

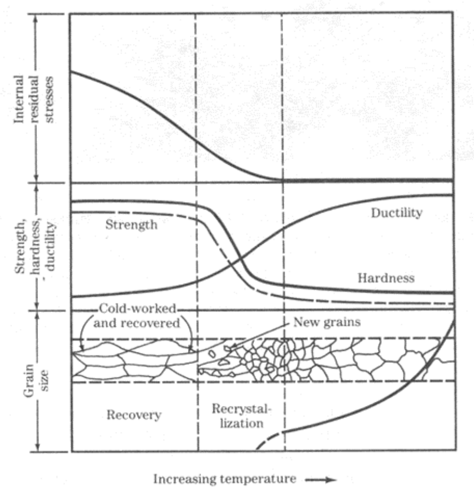


Figure 2.2: Recrystallization phase

Much of the information on non-equilibrium distribution, size and type of phases has come from experiments. The results are presented in a time-temperature-transformation (TTT) diagram shown in Figure 2.2. As a sample is cooled, the temperature will decrease as shown in curve #1 in Figure 2.3. At point A, pearlite (a mixture of ferrite and cementite) will start to form from austenite. At the time and temperature associated with point B, the austenite will have completely transformed to pearlite. There are many possible paths through the pearlite regions. Slower cooling causes coarse Pearlite, while fast cooling causes fine pearlite to form.

Cooling can produce other phases. If a specimen were cooled at a rate corresponding to curve #2 in Figure 2.3, martensite, instead of Pearlite, would begin to form at Ms temperature (point C), and the pearlite would be completely transformed to martensite at temperature Ms. Martensite causes increased hardness in steels.

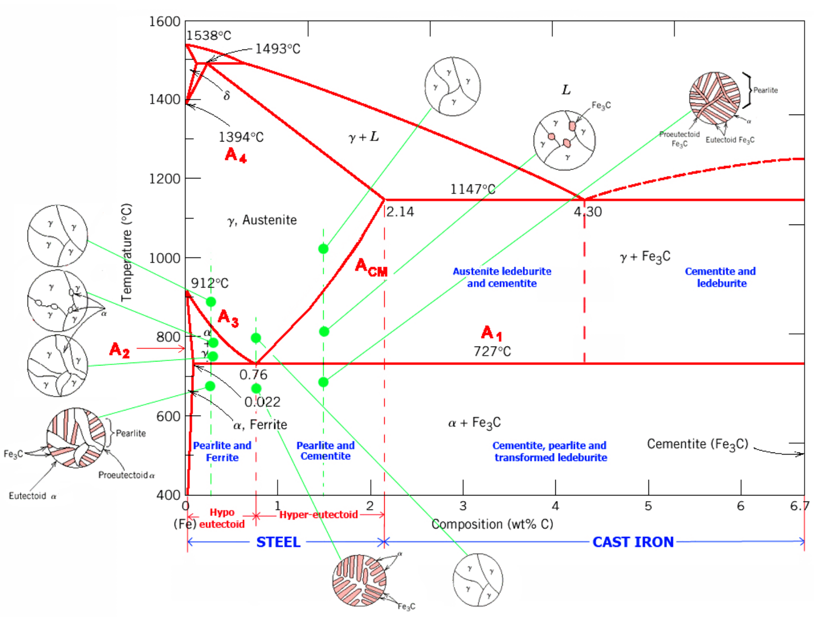


Figure 2.3: Iron-Carbon phase diagram

α = ferrite (BCC iron) δ = delta ferrite (BCC iron)

ɣ = austenite (FCC iron) Fe3C = iron carbide = cementite

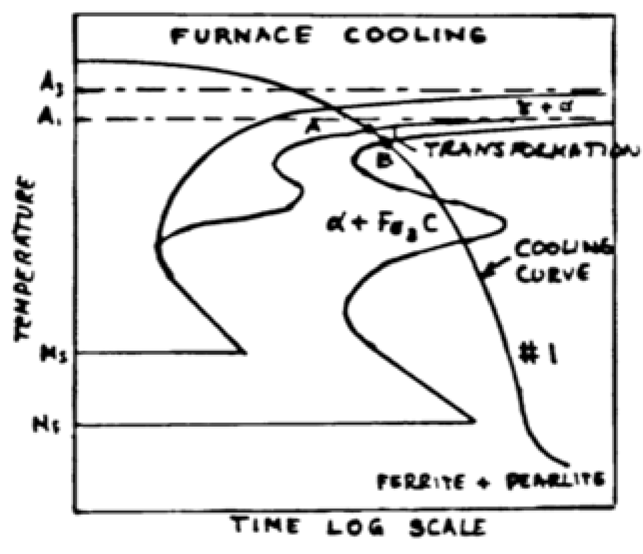


Figure 2.4: Typical TTT curve for a steel

Unfortunately, hardness in steels also produces brittleness. The brittleness is usually associated with low impact energy and low toughness. To restore some of the toughness and impact properties it is frequently necessary to "temper" or "draw" the steels.

This is accomplished by heating the steel to a temperature between 260ºC and 540ºC. Tempering removes some of the internal stresses and introduces recovery processes in the steel without a large decrease in hardness or strength.

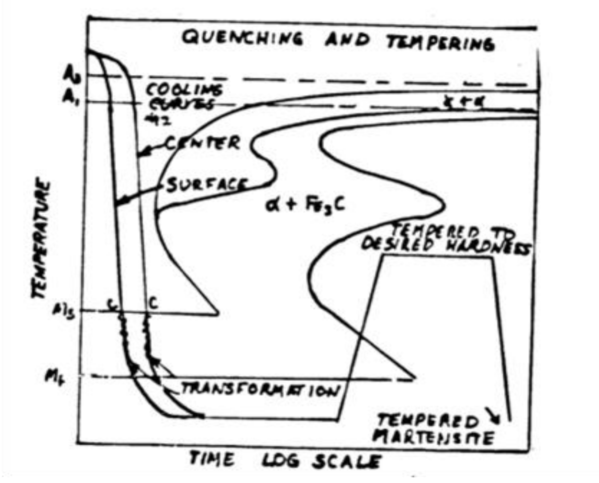


Figure 2.5: Non-equilibrium cooling to obtain martensite

To obtain the desired mechanical properties it is necessary to cool steel from the proper temperature at the proper rates and temper them at the proper temperature and time.

Common steels, which are really solid solutions of carbon in iron, are body-centered-cubic. However, the carbon has a low solubility in bcc iron and precipitates as iron carbide when steel is cooled from 870ºC. The processes of precipitation can be altered by adjusting the cooling rate. This changes the distribution and size of the carbide which forms a laminar structure called pearlite during slow cooling processes.

If a steel is quenched into water or oil from 870ºC a metastable phase called martensite forms, which is body-centered-tetragonal. This phase sets up large internal stresses and prevents carbide from forming. The internal stresses produce a high hardness and unfortunately, low toughness. After cooling, to restore toughness, steels are tempered by reheating them to a lower temperature around 426ºC and cooling. The tempering relieves the internal stresses and also allows some iron carbide to form. It also restores ductility.

4	**EQUIPMENT / TOOLS** i. Low carbon steel ii. Saw iii. Files iv. Vice v. Ruler vi. Scriber vii. Electric furnace viii. Quenching bath and container ix. Leather Glove x. Pair of tongs xi. Brick
5	**SAFETY PRECAUTIONS** i. Perform only those experiments authorized by your instructor. Carefully follow all instructions, both written and oral. Unauthorized experiments are not allowed. ii. Be prepared for your work in the laboratory. Read all procedures thoroughly before entering the laboratory. Never fool around in the laboratory. Horseplay, practical jokes, and pranks are dangerous and prohibited. iii. Always work in a well-ventilated area. iv. Observe good housekeeping practices. Work areas should be kept clean and tidy at all times. v. Be alert and proceed with caution at all times in the laboratory. Notify the instructor immediately of any unsafe conditions you observe.
6	**PROCEDURE** i. Cut the size of specimens 10mmx10mmx10mm. (**Refer Figure 2.3**) ii. Numbers of specimen to be provided are a total of four specimens.

i. Label the specimen 1 (without heat treatment), 2 (annealing), 3 (normalizing) and 4 (quenching).

ii. Enter the specimens (2 - 4) into the furnace. Closed the furnace and switch on.

iii. Furnace set as follows:

a) Heating temperature, 850^{0}C.

b) The rate of temperature rise until the temperature heating, 50^{0}C per minute.

c) Soaking duration, 30 minute.

i. Cool off the specimen is either in a furnace (annealing), ordinary air by placing it on a brick (normalizing) and immersed in quenching bath (quenching).

Precautions:

i. Make sure that there is no overheating otherwise the specimen may get spoiled.

ii. The pair of tongs used for removing the specimen from the furnace should be dry and should grip the piece firmly.

iii. Quench the specimen slowly.

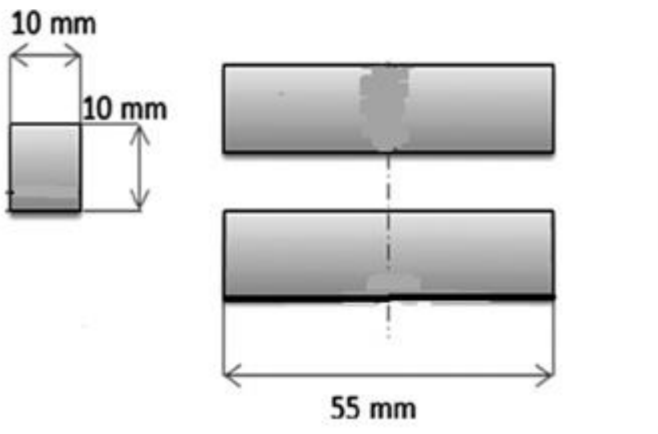


Figure 2.3: Dimension of specimen

7 **RESULT/DATA**

State your observation of the specimen. (Refer Table 1.1)

Table 2.1: Table observation of specimens through various heat treatment processes.

Heat Treatment	Observation	Noted
Without heat treatment		
Annealing		
Normalizing		
Quenching		

8 **DISCUSSION**

i. Find the schematic diagram of grain structure and discuss the effect heat treatment process below based on grain structures:

a) Annealing

b) Normalizing

c) Quenching

i. Based on your observation (Refer table 2.1), explain why these situation occur?

9 **CONCLUSION AND RECOMMENDATION**

10 **REFERENCES**

APPENDIX 3: EXPERIMENT 3 HARDNESS TEST

POLITEKNIK MALAYSIA

MECHANICAL ENGINEERING DEPARTMENT

ACADEMIC SESSION: ____________________

DJJ30113 – MATERIAL SCIENCE AND ENGINEERING

PRACTICAL WORK	:	HARDNESS TEST		
PRACTICAL WORK DATE	:			
LECTURER'S NAME	:			
GROUP NO.	:		CLASS:	

No.	STUDENT ID & NAME	TOTAL MARKS

DATE SUBMIT:	**DATE RETURN:**

RUBRIC

	NO	CRITERIA	EXCELLENT	VERY GOOD	GOOD	FAIR	UNSATISFACTORY	MARKS
			5	4	3	2	1	
CL02P	A	**Introduction**	· Very well-written, clearly explain the relevant experiment background.	· Good written, explain the relevant experiment background.	· Experiment background is nearly complete but does not provide for some minor information	· Experiment background is lack of complete with some minor information	· Very little experiment background information provided or information is incorrect	[/5]
	B	**Objective**	· Objective is clearly identified	· Objective is clearly identified	· Objective is identified.	· Objective is less identified.	· Objective is not identified.	[/5]
	C	**Safety Procedure & Equipment**	· Safety procedures are listed in clear steps. Each step is numbered and in a complete sentence. All necessary laboratory equipment included and listed in an organized manner	· Safety procedures are listed. Each step is numbered and in a complete sentence. · All necessary laboratory equipment included and listed.	· Safety procedures are listed in clear steps but not numbered and/or in complete sentences. All necessary laboratory equipment included but not listed in any particular order	· Safety procedures are less listed in and not numbered and/or in complete sentences. A few necessary laboratory equipment included and not listed in any particular order.	· Safety procedures are not listed. There is not a list of the necessary laboratory equipment	[/5]
	D	**Methods**	· Narrative and details methods/procedural explanation	· Methods/procedural explanation are stated but not in passive work.	· Narrative missing some methods details or observations or includes insignificant procedural details	· Narrative missing nearly overall methods details or observations or not includes insignificant procedural details	· Not written in narrative form. Procedural/methods steps are incorrect	[/5]
	E	**OBSERVATION & ANALYSIS**	There has a detail observation of the result. All figure, table and graph are correctly down, are numbered and in a complete sentence.	The data was observed with example calculation. All figure, table and graph are correctly down.	All figure, table and graph are correctly down, but some have minor problems or could still be improved.	There has an observation of the result but many incorrect data.	Figures and tables contain errors or are poorly constructed, have missing titles, captions or numbers, units missing or incorrect.	[/5]
	F	**ARGUMENT OF THE RESULT**	· Results have been interpreted correctly and discussed, good understanding of results is conveyed. Student clearly makes connections between practical work and theory	· Results have been interpreted correctly and discussed, good understanding of results is conveyed. Student less makes connections between practical work and theory	· Some of the results have been correctly interpreted and discussed. Student fails to make one or two connections to underlying theory.	· Some of the results have been correctly interpreted and discussed. Student fails to make one or two connections to underlying theory.	· "explains away" results with incorrect explanation.	[/5]
	G	**Conclusion**	· Accurate statement of the results of experiment indicates whether results support objectives.	· Less accurate statement of the results of experiment indicates whether results support objectives.	· A statement of the results of the experiment indicates whether results support the objectives	· A statement of the results of the experiment indicates but results did not support the objectives	· No conclusion was included or shows little effort and reflection on the experiment.	[/5]
	H	**References**	· All sources (information and graphics) are accurately documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are accurately documented. Some are primary scholarly sources but two or more are not. References are not directly cited in text.	· Less sources (information and graphics) are accurately documented. No primary scholarly sources. References are not directly cited in text.	· Sources are not documented or information is plagiarized from sources.	[/5]
							TOTAL MARKS	[/40]
							PERCENTAGES (/45) X 20 MARKS	[/20]

RUBRIC

ATTRIBUTE	SUBATTRIBUTE	SCORE DESCRIPTION					SCORE
		1	2	3	4	5	
TEAMWORK	FOSTER GOOD RELATIONSHIP	No clear evidence of ability to foster good relationships and work together effectively with other group members towards goal achievement.	able to foster relationship and work together with other group members towards goal achievement but with limited affect and require improvements.	able to foster relationship and work together with other group members towards goal achievement with some effect(s) and require minor improvements.	able to foster good relationship and work together with other group members towards goal achievement.	high ability to foster good relationship and work together effectively with other group members towards goal achievement.	
	Alternate roles	no clear evidence of ability to assume alternate roles as a group leader and group members demonstrated in practice.	Attempt to demonstrate in practice the ability the ability to alternate roles as a group leader and group members but with limited effect and require improvements.	Able to demonstrate in practice the ability to assume alternate roles as a group leader and group members with some effect(s) and require minor improvements.	Able to demonstrate in practice the ability to assume alternate roles as a group leader and a group member to achieve the same goal.	Show clear evidence to assume alternate roles as a group leader and a group member demonstrated in practice.	
	Respect and accept opinion	Not able to respect and accept opinion of others that leads to conflicts.	Limited respect and acceptance of others' opinions in achievement group's objectives.	Able to respect and accept opinion of others in achieving group's objectives.	Able to well respect and accept opinion of others in achieving group's	Able to very well respect and accept opinion of others in achieving group's objectives.	
Total Marks							/15
Percentages (_ /15) x 20							

1 **LEARNING OUTCOMES (LO)**

i. Performed appropriate material testing according to the Standard Operating Procedures. (CLO2, P4, PLO5)

ii. Demonstrate the ability to work individually and in groups to complete assigned tasks during the practical work session. (CLO3, A3, PLO9)

2 **OBJECTIVE**

At the end of the lab session students should be able to:

a. Investigate the processes of heat treating of steel

b. Study hardness testing and its limits.

c. Examine microstructures of steel in relation to hardness.

3 **THEORY**

HARDNESS TEST (ROCKWELL)

The test machine measures the depth of impression rather than the diameter. The measurement is read on the dial of a micrometer depth gauge which is connected to the indenter. The indenter used in this test is either a hardened steel ball or a carefully ground diamond cone.

Low value of Rockwell Hardness Number shows a deep depth of indentation and higher value of Rockwell Hardness Number shows a shallow depth of indentation. The principle of this test is comparing the difference of depth of penetration of the indenter when using forces of two different values. A minor force is first applied and the scales are set to read zero, then a major force is applied at the same indentation and the increased depth of penetration is shown on the scales of the machine as a direct reading of hardness without the need for calculation or conversion tables.

Figure 3.1: Rockwell Hardness Machine.

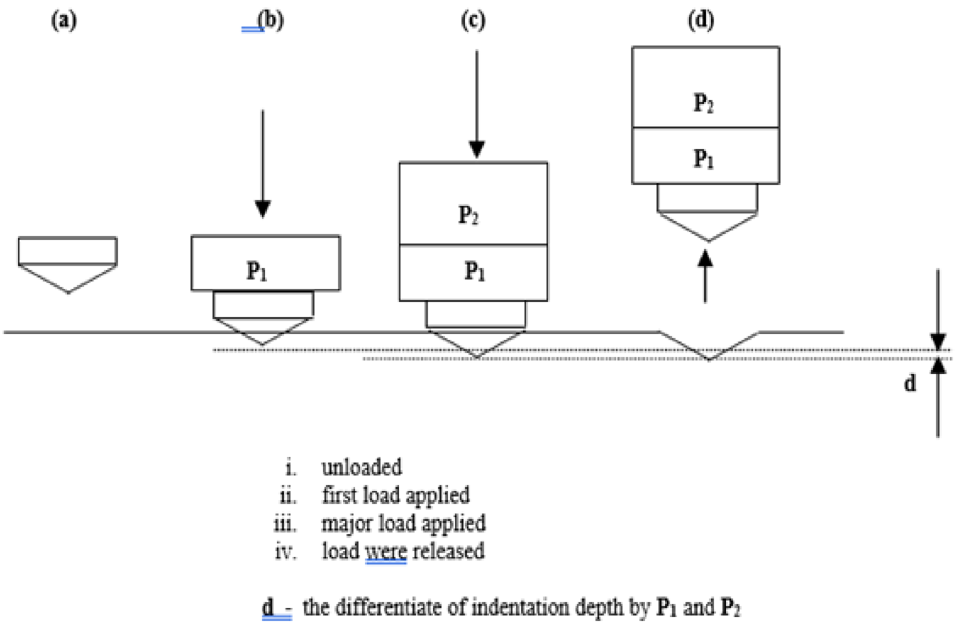


Figure 3.2: The principle of this Rockwell hardness test which is comparing the difference of depth of penetration of the indenter when using forces of two different values.

The indenters most commonly used are :

i. diamond cone with an apex angle of 120^0
ii. hard steel ball by varies of diameter 1/16, 1/8, ¼ dan ½ inches.

Table 3.1: Standard loads indenter

Scale	Indenter	Loads		
		First	Major	Total
B	Hard steel ball ∅ 1.6mm	10	90	100
C	Diamond cone with apex angle of 120°	10	140	150

A series of scale for Rockwell hardness Number (HR) because of it is using few types of indenter and loads. Standard load for indentation are 60, 100 and 150kg. Each hardness scale differentiates by the letter A, B, C and etc as shown in the table below.

The scale C (written as HRC) usually used for hardened steel and scale B (HRB) used for non-hardened steel or hardened non-ferrous alloys. If the Rockwell Hardness Number (HR) is 55 by using C scale, it is written as 55 HRC.

Table 3.2: Scale of Rockwell Hardness Test

Scale	Symbol	Indenter	Additional loads (kg)	Applications
A	HRA	Diamond cone	60	Hardened steel thin plate
B	HRB	Steel ball ø 1/16	100	Low carbon steel and medium carbon steel with no heat treatment
C	HRC	Diamond cone	150	Hardened tempered steel and alloy steel
D	HRD	Diamond cone	100	Hardened iron-steel
E	HRE	Steel ball ø 1/8	100	Cast iron, aluminium alloy and magnesium alloy
F	HRF	Steel ball ø 1/16	60	Brass and cuprum
G	HRG	Steel ball ø 1/16	150	Copper, guns metal and cuprum beryllium
H	HRH	Steel ball ø 1/8	60	Soft aluminium and thermoplastic
K	HRK	Steel ball ø 1/8	150	Aluminium and magnesium alloy
L	HRL	Steel ball ø ¼	60	Soft thermoplastic
M	HRM	Steel ball ø ¼	100	Thermoplastic
R	HRR	Steel ball ø ¼	60	Very soft thermoplastic and rubbers

4 **EQUIPMENT / TOOLS**

i. Specimen (1, 2, 3, 4) from the previous experiment.

ii. Digital Rockwell types hardness tester

5 **SAFETY PRECAUTIONS**

i. Perform only those experiments authorized by your instructor. Carefully follow all instructions, both written and oral. Unauthorized experiments are not allowed.

ii. Be prepared for your work in the laboratory. Read all procedures thoroughly before entering the laboratory. Never fool around in the laboratory. Horseplay, practical jokes, and pranks are dangerous and prohibited.

iii. Always work in a well-ventilated area.

iv. Observe good housekeeping practices. Work areas should be kept clean and tidy at all times.

v. Be alert and proceed with caution at all times in the laboratory. Notify the instructor immediately of any unsafe conditions you observe.

6 **PROCEDURE**

i. Make sure the indenter, material and platen are clean.

ii. Pick a spot for your test at least or 3mm from edges and dents from previous tests.

iii. Start with the loading handle in the mirror load (forward) position.

iv. Centre the fine adjustment knob.

v. Turn the crank to bring the material into contact with the indenter. Keep turning until the 'SET' line is near the horizontal mark on the screen.

vi. Use the fine adjustment knob to line up the Horizontal and 'SET' marks precisely.

vii. Push the loading handle away from yourself to apply the major load.

viii. After the screen display stops moving, return the loading handle to the minor load position.

ix. Record and repeat the reading for at least 4 times.

Precautions:

i. Clean the specimen properly before testing the hardness.

RESULT/DATA

Using specimen (from the previous experiment), measure the hardness of all specimen with Rockwell machine. State your observation of the specimen. (Refer Table 3.2)

Table 3.2: **Data of Rockwell hardness test.**

Specimen	Rockwell hardness number				
	Trial 1	Trial 2	Trial 3	Trial 4	Average value
Without heat treatment					
Annealing					
Normalizing					
Quenching					

Table 3.3 Data of Brinell Hardness Tester

Heat Treatment Technique	Hardness Number (B.H.N)	
	Before Heat treatment	After Heat Treatment
Annealing	106	129
Hardening	106	427
Normalizing	106	156

Source: (Rahman et al., 2016)Rahman, S. M. M., Karim, K. E., & Simanto, M. H. S. (2016).

	Data Analysis i. Compute the Rockwell hardness number and compare with from the chart. ii. Graph Rockwell Hardness vs Brinell Hardness
8	**DISCUSSION** Discuss this practical result with reference to the second practical result of heat treatment. i. State the specimens indicate that recorded the highest reading and the lowest for Rockwell hardness test. ii. Why does this happen to these specimens? iii. Why do you need more than one Rockwell scale?
9	**CONCLUSION** Compare the results of the Rockwell test graph and the Brinell test graph.
10	**REFERENCES**

APPENDIX 4: EXPERIMENT 4 DYE PENETRANT INSPECTION

POLITEKNIK MALAYSIA

MECHANICAL ENGINEERING DEPARTMENT

ACADEMIC SESSION: ____________________

DJJ30113 – MATERIAL SCIENCE AND ENGINEERING

PRACTICAL WORK	:	DYE PENETRANT INSPECTION		
PRACTICAL WORK DATE	:			
LECTURER'S NAME	:			
GROUP NO.	:		CLASS:	

No.	STUDENT ID & NAME	TOTAL MARKS

DATE SUBMIT:	DATE RETURN:

RUBRIC

	NO	CRITERIA	EXCELLENT	VERY GOOD	GOOD	FAIR	UNSATISFACTORY	MARKS
			5	4	3	2	1	
CL02P	A	**Introduction**	· Very well-written, clearly explain the relevant experiment background.	· Good written, explain the relevant experiment background.	· Experiment background is nearly complete but does not provide for some minor information	· Experiment background is lack of complete with some minor information	· Very little experiment background information provided or information is incorrect	[/5]
	B	**Objective**	· Objective is clearly identified	· Objective is clearly identified	· Objective is identified.	· Objective is less identified.	· Objective is not identified.	[/5]
	C	**Safety Procedure & Equipment**	· Safety procedures are listed in clear steps. Each step is numbered and in a complete sentence. All necessary laboratory equipment included and listed in an organized manner	· Safety procedures are listed. Each step is numbered and in a complete sentence. · All necessary laboratory equipment included and listed.	· Safety procedures are listed in clear steps but not numbered and/or in complete sentences. All necessary laboratory equipment included but not listed in any particular order	· Safety procedures are less listed in and not numbered and/or in complete sentences. A few necessary laboratory equipment included and not listed in any particular order.	· Safety procedures are not listed. There is not a list of the necessary laboratory equipment	[/5]
	D	**Methods**	· Narrative and details methods/procedural explanation	· Methods/procedural explanation are stated but not in passive work.	· Narrative missing some methods details or observations or includes insignificant procedural details	· Narrative missing nearly overall methods details or observations or not includes insignificant procedural details	· Not written in narrative form. Procedural/methods steps are incorrect	[/5]
	E	**OBSERVATION & ANALYSIS**	There has a detail observation of the result. All figure, table and graph are correctly down, are numbered and in a complete sentence.	The data was observed with example calculation. All figure, table and graph are correctly down.	All figure, table and graph are correctly down, but some have minor problems or could still be improved.	There has an observation of the result but many incorrect data.	Figures and tables contain errors or are poorly constructed, have missing titles, captions or numbers, units missing or incorrect.	[/5]
	F	**ARGUMENT OF THE RESULT**	· Results have been interpreted correctly and discussed, good understanding of results is conveyed. Student clearly makes connections between practical work and theory	· Results have been interpreted correctly and discussed, good understanding of results is conveyed. Student less makes connections between practical work and theory	· Some of the results have been correctly interpreted and discussed. Student fails to make one or two connections to underlying theory.	· Some of the results have been correctly interpreted and discussed. Student fails to make one or two connections to underlying theory.	· "explains away" results with incorrect explanation.	[/5]
	G	**Conclusion**	· Accurate statement of the results of experiment indicates whether results support objectives.	· Less accurate statement of the results of experiment indicates whether results support objectives.	· A statement of the results of the experiment indicates whether results support the objectives	· A statement of the results of the experiment indicates but results did not support the objectives	· No conclusion was included or shows little effort and reflection on the experiment.	[/5]
	H	**References**	· All sources (information and graphics) are accurately documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are documented. All references are from primary scholarly literature relevant to report.	· All sources (information and graphics) are accurately documented. Some are primary scholarly sources but two or more are not. References are not directly cited in text.	· Less sources (information and graphics) are accurately documented. No primary scholarly sources. References are not directly cited in text.	· Sources are not documented or information is plagiarized from sources.	[/5]
							TOTAL MARKS	[/40]
							PERCENTAGES (/45) X 20 MARKS	[/20]

1	**LEARNING OUTCOMES (LO)** Performed appropriate material testing according to the Standard Operating Procedures. (P4, PLO5)
2	**OBJECTIVE** At the end of the lab session students should be able to perform a non-destructive testing (dye penetrant) and see the results generated from the process.

THEORY

Dye penetrant inspection (**DPI**), also called **liquid penetrant inspection** (**LPI**) or **penetrant testing** (**PT**), is a widely applied and low-cost inspection method used to locate surface-breaking defects in all non-porous materials (metals, plastics, or ceramics). The penetrant may be applied to all non-ferrous materials and ferrous materials, although for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components.

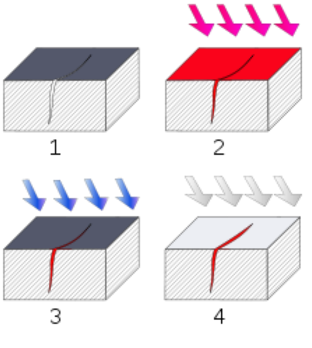


Figure 4.1 Diagram of Dye penetrant inspection (DPI)

i. Section of material with a surface-breaking crack that is not visible to the naked eye.
ii. Penetrant is applied to the surface.
iii. Excess penetrant is removed.
iv. Developer is applied, rendering the crack visible.

5	**SAFETY PRECAUTIONS** i. Perform only those experiments authorized by your instructor. Carefully follow all instructions, both written and oral. Unauthorized experiments are not allowed. ii. Be prepared for your work in the laboratory. Read all procedures thoroughly before entering the laboratory. Never fool around in the laboratory. Horseplay, practical jokes, and pranks are dangerous and prohibited. iii. Always work in a well-ventilated area. iv. Observe good housekeeping practices. Work areas should be kept clean and tidy at all times. v. Be alert and proceed with caution at all times in the laboratory. Notify the instructor immediately of any unsafe conditions you observe.
	PROCEDURE **i. Pre-cleaning**: Spray the cleaner (no.1) to the surface. This is to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Then wipe dry the surface with clean cloth. **ii. Application of penetrant**: Spray the penetrant (no.2) to cover all areas to be inspected and leave it for 10-30 minutes. The penetrant is allowed time to soak into any flaws (generally 10 to 30 minutes). The soak time mainly depends upon the material being testing and the size of flaws sought. As expected, smaller flaws require a longer penetration time. Due to their incompatible nature one must be careful not to apply visible red dye penetrant to a sample that may later be inspected with fluorescent penetrant.

	iii. Excess Penetrant Removal: Clean off the no.2 penetrant with a lint-free cloth soaked with no.1 cleaner. When using solvent remover no.1 and lint-free cloth it is important to not spray the solvent on the test surface directly, because this can the remove the penetrant from the flaws. This process must be performed under controlled conditions so that all penetrant on the surface is removed (background noise) but penetrant trapped in real defects remains in place. **iv. Application of Developer**: Spray developer (no.3) an even thin enough to provide transparency, as too thick a layer will interfere with interpretation of fine cracks. The developer draws penetrant from defects out onto the surface to form a visible indication, a process similar to the action of blotting paper. Any colored stains indicate the positions and types of defects on the surface under inspection. **v. Inspection**: Inspect for surface cracks in natural daylight or articificial white light and interpret according to established procedures. Inspection of the test surface should take place after a 10 minute development time. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye, but this should not be done when using fluorescent penetrant. Also of concern, if one waits too long after development the indications may “bleed out” such that interpretation is hindered.
7	**RESULT/DATA** Identify the location and the shape of crack on the surface of inspected area.

8	**DISCUSSION** i. Discuss the result. i. Discuss the advantages and disadvantages using dye penetrant test?
9	**CONCLUSION AND RECOMMENDATION**
10	**REFERENCES**

APPENDIX 5: REPORT TEMPLATE

POLITEKNIK MALAYSIA

MECHANICAL ENGINEERING DEPARTMENT

ACADEMIC SESSION: ____________________

DJJ30113 – MATERIAL SCIENCE AND ENGINEERING

PRACTICAL WORK	:			
PRACTICAL WORK DATE	:			
LECTURER'S NAME	:			
GROUP NO.	:		CLASS:	

No.	STUDENT ID & NAME	TOTAL MARKS

DATE SUBMIT:	DATE RETURN:

Title:

Objective:

Introduction:

Tools Equipment:			
1.		9.	
2.		10.	
3.		11.	
4.		12.	
5.		13.	
6.		14.	
7.		15.	
8.		16.	

Safety precautions:

1. ....
2. ....
3. ....
4. ....
5. ....

Procedure

Result:
Discussion:

Conclusion:
References:

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