LABORATORY MANUAL

Material Science

4th Semester BE

DEPARTMENT OF MECHANICAL ENGINEERING

Jorhat Engineering College
Jorhat – 785007 (Assam)

STUDENT PROFILE	
NAME :	
ROLL NUMBER :	
SECTION :	
SEMESTER :	4^{th} Semester
YEAR :	

PERFORMANCE RECORD		
EXP. NO.	**TITLE OF EXPERIMENT**	**REMARKS / GRADE**
1	Rockwell Hardness Test.	
2	Brinell Hardness Test.	
3	Charpy Pendulum Impact Test.	
4	Tension Test.	

Course Outcomes: After completion of the course, the students will able to

CO1: Determine the hardness of metals

CO2: Determine the yield strength, ultimate tensile strength and ductility of metals

CO3: Determine the impact strength of metals

OFFICE USE	
Checked By :	
Overall Grade / Marks :	
Signature of Teacher :	

Experiment No. 1

TITLE: Rockwell Hardness Test.

OBJECTIVE:

To determine hardness of a flat mild steel and high carbon steel specimen.

THEORY:

The hardness of a material is its resistance to penetration under a localized pressure or resistance to abrasion. Hardness test provides an accurate, rapid and economical way of determining the resistance of the material to deformation.

In Rockwell hardness test, the instrument measures the depth of penetration made by a particular indenter under a definite amount of load and indicates it as a dimensionless hardness number on a Dial Indicator.

Initial a Preliminary Test Force (Minor Load) is applied to the test piece and the Indenter penetrates through a certain depth into the test piece. Since the surface of the test piece may not be fully free from irregularities, hence this initial penetration eliminates any effect of surface finish on the test results and sets the Zero Reference Line for the test procedure.

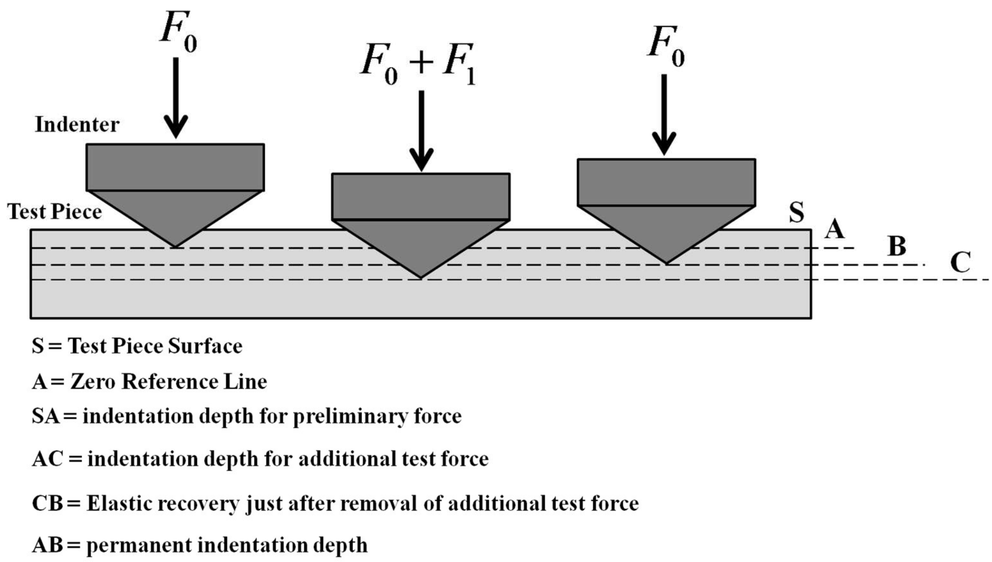


Figure 1.1: *Indentation under different test loads*

Next, an Additional Test Force (Major Load) is applied and the Indenter penetrates through the maximum depth possible. This load is kept in application for a definite amount of time (dwell time) and then released to allow elastic recovery in the test piece. There will remain some residual depth of penetration (Permanent Depth of Penetration) on the test piece and this residual depth is converted into a dimensionless Hardness Number as indicated on the Dial Indicator.

A variety of penetrators and standard loads can be used; giving a series of different scales identified by capital letters A, B, C, D, E, F, G, H, K, N and T. Refer **Table 1.1** for all the details.

The Rockwell method is much faster than any other methods of hardness testing and produces an indentation of the order of 0.005 inch. It is therefore suitable for thin specimen.

PRECAUTIONS:

- The thickness of the test piece should be at least ten times the permanent indentation depth for cone indenters and fifteen times the permanent indentation depth for ball indenters.
- The test should be carried out at ambient temperature within the limits of $10°C$ to $35°C$. However, because temperature variations may affect the results, hence for better results, the test can be carried under controlled environment.
- The test surface should be smooth and even, free from oxide scale, foreign matters and, in particular, completely free from lubricants. Exceptions include reactive metals, like titanium, which might adhere to the indenter. In such situations, a suitable lubricant such as kerosene may be used. The use of a lubricant shall be reported on the test report.

PROCEDURE:

1. Place the Test Piece on the Test Piece Bed.
2. Press the Handle download to unload the apparatus. i.e. the External Loads (major load) are not in application.
3. Keep pressing the Handle download and raise the Bed by rotating the Hand Wheel in clockwise direction. Continue raising the Bed even after the initial contact between the Test Piece and Indenter is made, till the needle on the Small Dial is aligned with the SET mark. This indicates that an initial load of 10 kg (Pre-load / minor load) has been applied on the Test Piece.
4. Manually rotate the Large Dial to align the ZERO Mark with the large needle.

5. Now rotate the Handle on the other direction to apply the External Loads. Keep the External Loads in application for at least 21 seconds (dwell time).
6. After 21 seconds, unload the apparatus, as done in step 2 and record the reading on the Large Dial. This will be the Rockwell Hardness Number for the Test Piece.
7. Lower the Bed by rotating the Hand Wheel in anti-clockwise direction and collect the Test Piece.

OBSERVATION TABLE – 1

<table>
<tr><th>Sl. No.</th><th>Specimen</th><th>Reading (HRB)</th><th>Mean Hardness (HRB)</th></tr>
<tr><td>1</td><td rowspan="3">Flat Mild Steel Plate</td><td></td><td rowspan="3"></td></tr>
<tr><td>2</td><td></td></tr>
<tr><td>3</td><td></td></tr>
</table>

OBSERVATION TABLE – 2

<table>
<tr><th>Sl. No.</th><th>Specimen</th><th>Reading (HRC)</th><th>Mean Hardness (HRC)</th></tr>
<tr><td>1</td><td rowspan="3">Flat High Carbon Steel Plate</td><td></td><td rowspan="3"></td></tr>
<tr><td>2</td><td></td></tr>
<tr><td>3</td><td></td></tr>
</table>

RESULT:

1. The hardness of the mild steel test piece is found to be :
2. The hardness of the high carbon steel test piece is found to be :

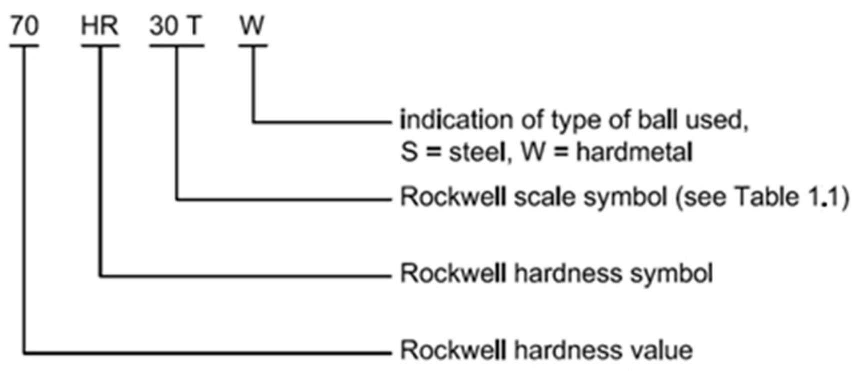


Figure 1.2: *Writing a particular Result after test [as per ISO 6508-1:2005(E)]*

Table 1.1: Rockwell Scales and Indenters *[as per ISO 6508-1:2005(E)]*

Rockwell Hardness Scale	**Hardness Symbol**	**Type of Indenter**	**Preliminary Test Force (F_0)**	**Additional Test Force (F_1)**	**Total Test Force (F)**	**Field of Application (Rockwell Hardness Test)**
A	HRA	120^0 Diamond cone	10 kgf	50 kgf	60 kgf	20 HRA to 88 HRA
B	HRB	1/16 inch Ball	10 kgf	90 kgf	100 kgf	20 HRB to 100 HRB
C	HRC	120^0 Diamond cone	10 kgf	140 kgf	150 kgf	20 HRC to 70 HRC
D	HRD	120^0 Diamond cone	10 kgf	90 kgf	100 kgf	40 HRD to 77 HRD
E	HRE	1/8 inch Ball	10 kgf	90 kgf	100 kgf	70 HRE to 100 HRE
F	HRF	1/16 inch Ball	10 kgf	50 kgf	60 kgf	60 HRF to 100 HRF
G	HRG	1/16 inch Ball	10 kgf	140 kgf	150 kgf	30 HRG to 94 HRG
H	HRH	1/8 inch Ball	10 kgf	50 kgf	60 kgf	80 HRH to 100 HRH
K	HRK	1/8 inch Ball	10 kgf	140 kgf	150 kgf	40 HRK to 100 HRK
15N	HR15N	120^0 Diamond cone	3 kgf	12 kgf	15 kgf	70 HR15N to 94 HR15N
30N	HR30N	120^0 Diamond cone	3 kgf	27 kgf	30 kgf	42 HR30N to 86 HR30N
45N	HR45N	120^0 Diamond cone	3 kgf	42 kgf	45 kgf	20 HR45N to 77 HR45N
15T	HR15T	1/16 inch Ball	3 kgf	12 kgf	15 kgf	67 HR15T to 93 HR15T
30T	HR30T	1/16 inch Ball	3 kgf	27 kgf	30 kgf	29 HR30T to 82 HR30T
45T	HR45T	1/16 inch Ball	3 kgf	42 kgf	45 kgf	10 HR45T to 72 HR45T

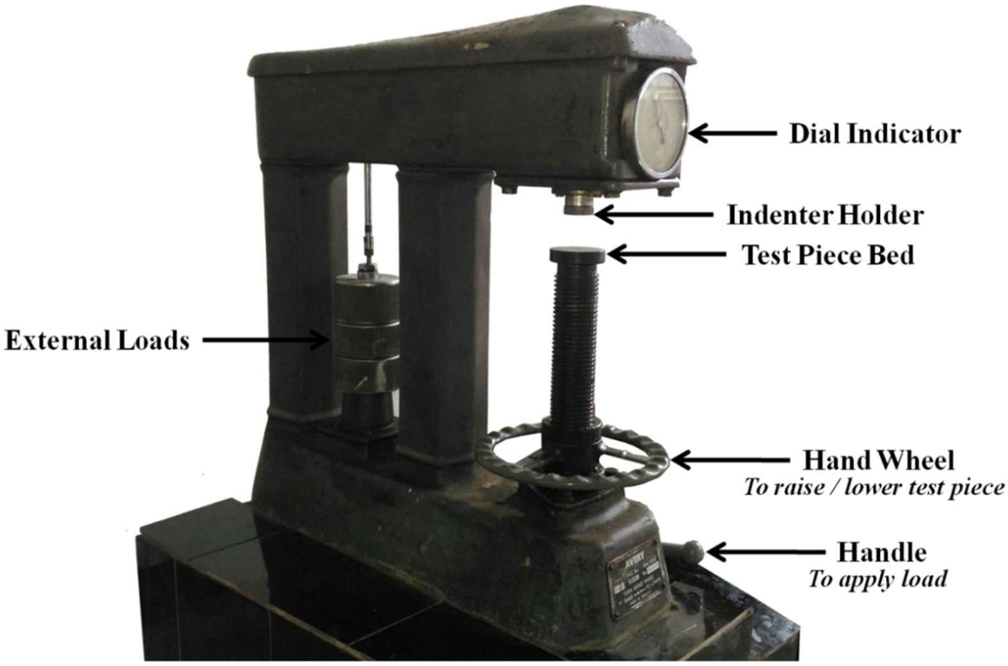


Figure 1.3: *Rockwell Hardness Apparatus*

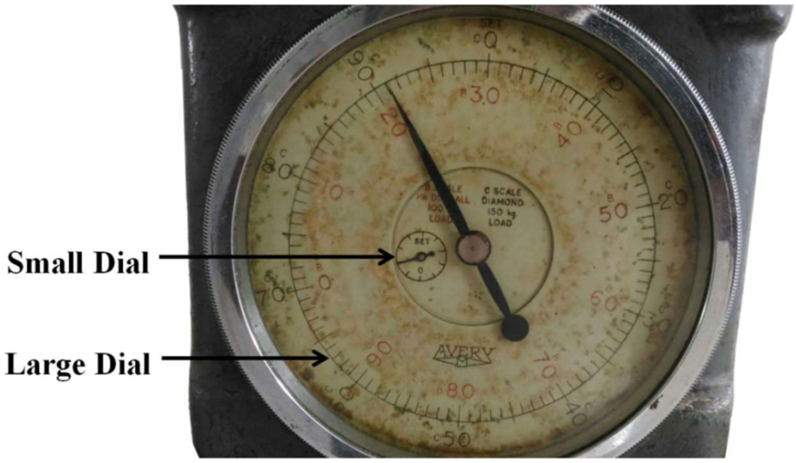


Figure 1.4: *The Dial Indicator showing both Rockwell B & C Scales*

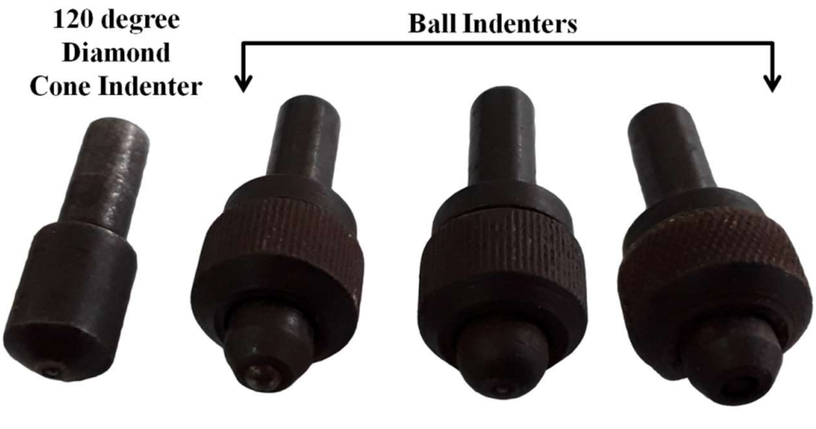


Figure 1.5: *Different types of Indenters*

REFERENCES

- ISO 6508-1:2005(E) document.

Exp. No. 1	**Title:** To determine hardness of a flat mild steel and high carbon steel specimen
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check **SEAL**

Experiment No. 2

TITLE: Brinell Hardness Test.

OBJECTIVE:

To determine hardness of a mild steel and high carbon steel specimen.

APPARATUS REQUIRED:

1. Brinell Hardness Tester [fig. 2.2 (a, b, c)]
   Manufactured by Zaklady Automatyki Przemyslowej, Poland
2. External Weights: 3000 kg for hard material, 1500 kg for intermediate material, and 500 kg for soft material. Refer Table 2.1 for more details.
3. Steel Ball Indenter of 10 mm diameter [fig. 2.2 (c)]
4. Brinell Microscope [fig. 2.2 (d)]
   Manufactured by PZO Warszawa, Poland

THEORY:

The hardness of a material is its resistance to penetration under a localized pressure or resistance to abrasion. Hardness test provides an accurate, rapid and economical way of determining the resistance of material to deformation.

In this test, a Tungsten Carbide steel ball indenter of diameter D is pressed against the surface of the test piece by a gradually applied load P, and this force is maintained for a definite amount of time. The impression on the test piece so obtained is measured using an optical microscope and the required Brinell Hardness Number (BHN) or Brinell Hardness (HB) is calculated using the following relation:

$$\textbf{BHN or HB} = \frac{\textbf{Applied test force in kgf}}{\textbf{Area of impression in mm}^2} = \frac{\boldsymbol{P}}{\boldsymbol{A}}$$

Where,

$P =$ Applied Test Force in kgf.

$A =$ Indented area $= \pi(D/2)\left[D - (D^2 - d^2)^{1/2}\right]$

$D =$ Diameter of steel ball indenter = 10 mm

$d =$ Diameter of impression on the test piece

The BHN is expressed in kg/mm^2. For obtaining good results, the steel ball indenter used in this test should be well polished and free from any surface defects.

PRECAUTIONS:

- The thickness of the test piece should be at least 8-10 times the depth of indentation. Visible deformation at the back of the test piece can indicate that the test piece is too thin.

- The test should be carried out at ambient temperature within the limits of 10℃ to 35℃. However, because temperature variations may affect the results, hence for better results, the test can be carried under controlled environment.

- The test surface should be smooth and even, free from oxide scale, foreign matters and, in particular, completely free from lubricants.

- Brinell Hardness test is not recommended for materials above 650 HBW 10/3000.

PROCEDURE:

1. Place the test piece on the test piece Bed of the apparatus.

2. Raise the Bed by rotating the Hand Wheel in clockwise direction till the initial contact between the surface of the test piece and the indenter is made.

3. Place suitable External Weights on the Yoke and close the Release Valve. The amount of external weights attached corresponds to the test force that would be applied on the test piece.

4. Start pumping the hydraulic fluid by moving the Handle up-and-down to gradually increase the test force on the test piece, till the fluid overflows through the Overflow Valve. Overflow gives an indication that the maximum amount of test force has been applied on the test piece.

5. Keep the test force in application for about 15 seconds (dwell time).

6. Now, open the release valve to release the test force.

7. Lower the Bed and collect the test piece.

8. Measure the diameter of the impression by using the Brinell Microscope. Hence, calculate the area of impression and the required Brinell Hardness Number (BHN).

OBSERVATION TABLE – 1

Sl. No.	**Specimen**	**Diameter of steel ball Indenter (D) (mm)**	**Diameter of Impression (d) (mm)**	**Area of Impression (A) (mm^2)**	**BHN**	**Average BHN**
1	Flat Mild Steel Plate					
2						
3						

OBSERVATION TABLE – 2

Sl. No.	**Specimen**	**Diameter of steel ball Indenter (D) (mm)**	**Diameter of Impression (d) (mm)**	**Area of Impression (A) (mm^2)**	**BHN**	**Average BHN**
1	Flat High Carbon Steel Plate					
2						
3						

RESULT:

1. The hardness of the mild steel test piece is found to be :

2. The hardness of the high carbon steel test piece is found to be :

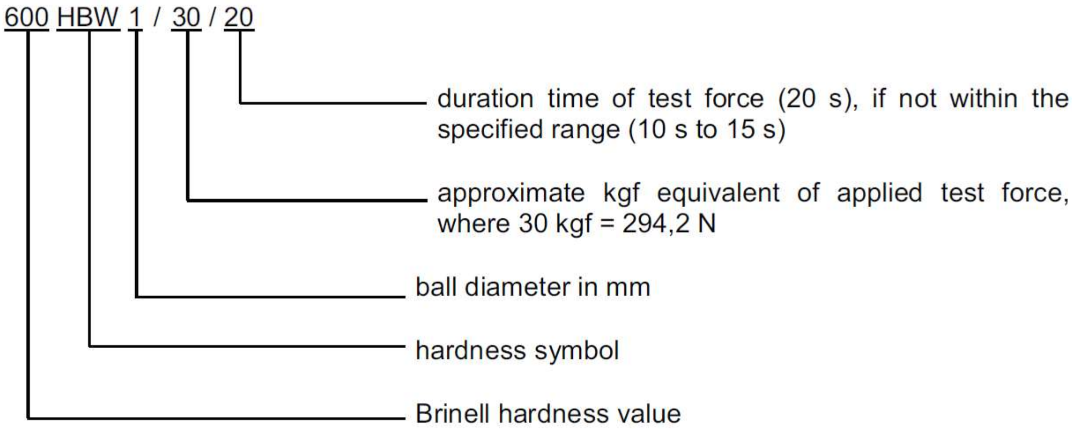
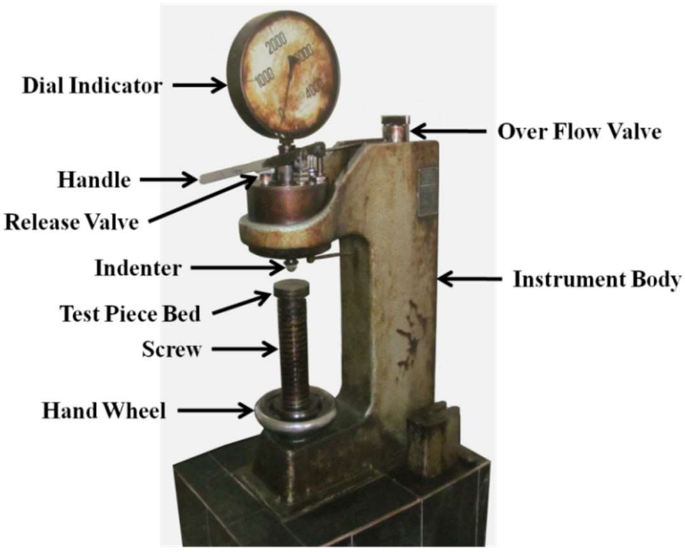
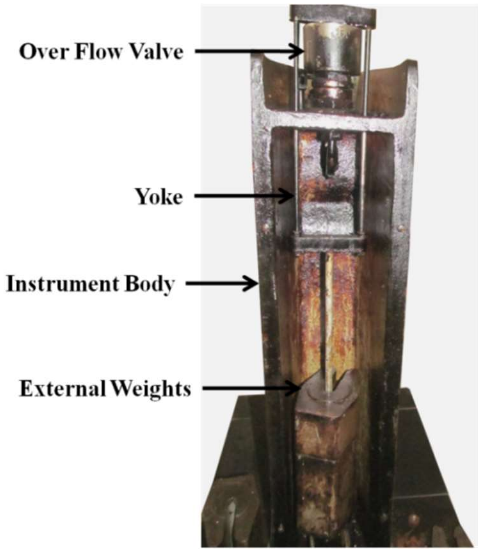


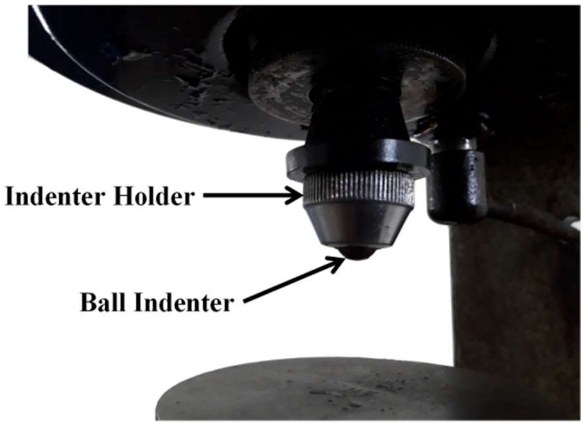
Figure 2.1: *Writing a particular Result after test [as per ISO 6506-1:2014(E)]*

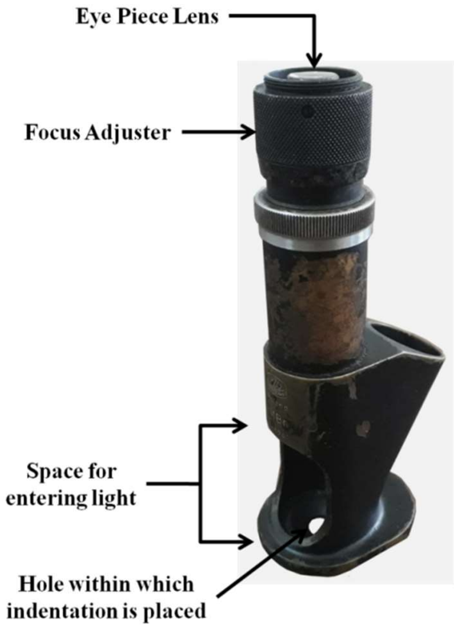
Hardness symbol **HBW** should be used if a Tungsten Carbide Ball Indenter is used, where **W** is the chemical symbol for Tungsten. Otherwise, if a Hardened Steel Ball indenter is used, the hardness symbol **HBS** should be used, where **S** denotes Hardened Steel.





(a) **(b)**





(c) **(d)**

Figure 2.2: **(a, b, c)** Different parts of the Brinell Hardness Testing apparatus ; **(d)** Brinell Microscope

Table 2.1: Test Forces for different hardness conditions and hardness range

Hardness Symbol	Ball Diameter (D) *(mm)*	Test force value (F) *(kgf)*	Force-diameter index (F/D^2)	Recommended Hardness Range (HBW)
HBW 10/3000	10	3000	30	95.5 to 650
HBW 10/1500	10	1500	15	47.7 to 327
HBW 10/1000	10	1000	10	31.8 to 218
HBW 10/500	10	500	5	15.9 to 109
HBW 10/250	10	250	2.5	7.96 to 54.5
HBW 10/125	10	125	1.25	3.98 to 27.2
HBW 10/100	10	100	1	3.18 to 21.8
HBW 5/750	5	750	30	95.5 to 650
HBW 5/250	5	250	10	31.8 to 218
HBW 5/125	5	125	5	15.9 to 109
HBW 5/62.5	5	62	2.5	7.96 to 54.5
HBW 5/31.25	5	31.25	1.25	3.98 to 27.2
HBW 5/25	5	25	1	3.18 to 21.8
HBW 2.5/187.5	2.5	188	30	95.5 to 650
HBW 2.5/62.5	2.5	62	10	31.8 to 218
HBW 2.5/31.25	2.5	31	5	15.9 to 109
HBW 2.5/15.625	2.5	16	2.5	7.96 to 54.5
HBW 2.5/7.8125	2.5	7.8125	1.25	3.98 to 27.2
HBW 2.5/6.25	2.5	6	1	3.18 to 21.8
HBW 1/30	1	30	30	95.5 to 650
HBW 1/10	1	10	10	31.8 to 218
HBW 1/5	1	5	5	15.9 to 109
HBW 1/2.5	1	3	2.5	7.96 to 54.5
HBW 1/1.25	1	1.25	1.25	3.98 to 27.2
HBW 1/1	1	1	1	3.18 to 21.8

REFERENCES:

- ISO 6506-1:2014(E) document.
- ASTM E10-15 and ASTM E10-01 document.

Exp. No. 2	**Title:** To determine hardness of a mild steel and high carbon steel specimen.
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check

SEAL

Experiment No. 3

TITLE: Charpy Pendulum Impact Test.

OBJECTIVE:

To determine impact resistance of an assigned specimen in the form of a notched bar flexure specimen.

APPARATUS REQUIRED:

- Charpy Pendulum Impact test apparatus (Fig. 3.3)
- V-notched bar. (Fig. 3.2)

THEORY:

A notched bar of definite geometry is broken with the single blow from a swinging pendulum, dropped from a definite height, and the energy absorbed during the impact is determined. This absorbed energy during the impact is the impact resistance of the test piece.

The pendulum of mass $m\ kg$ is raise to a definite height h_1 and then dropped freely to swing. The striker edge of the pendulum then hits the test piece at a point just opposite to the notch, breaks it into two pieces, and swings freely to a height h_2 on the other side. Energy absorbed during the process is the energy used in breaking the specimen, and that is equal to $mg(h_1 - h_2)$.

PROCEDURE:

1. Place the specimen on the supports and against the anvils as shown in Fig. 3.1. The notch should be on the side of the specimen away from the striking edge of the pendulum and directly in line with it.
2. Raise the pendulum to a certain height h_1 and hold it. Record the first dial reading and find the initial Potential Energy $(PE = mgh)$ stored in the pendulum at this height. The dial reading directly gives the value of mh. Multiply this value with g to get the value of PE.
3. Then release the pendulum to fall freely and rapture the specimen. The pendulum will then rise to a maximum height h_2 on the other side. Record the second dial reading and find the final PE for the pendulum at that height.

4. Now calculate the energy lost during the impact. This is the required impact resistance of the test specimen.

OBSERVATION:

Specimen	Initial PE of the Pendulum at height $h_1 = X_1$ Joule	Final PE of the Pendulum at height $h_2 = X_2$ Joule	Energy absorbed during impact $(X_1 - X_2)$ (Joule)	Average (Joule)
Mild Steel Bar				

RESULT:

The impact resistance of the given test specimen is found to be : ………………..… $\boldsymbol{KV_2}$

Here, KV is used to denote the impact resistance of the test piece. Letter $\boldsymbol{V}$ is used for V-notch and $\boldsymbol{U}$ for U-notch; and the subscript 2 in KV_2 denotes the striker radius in mm.

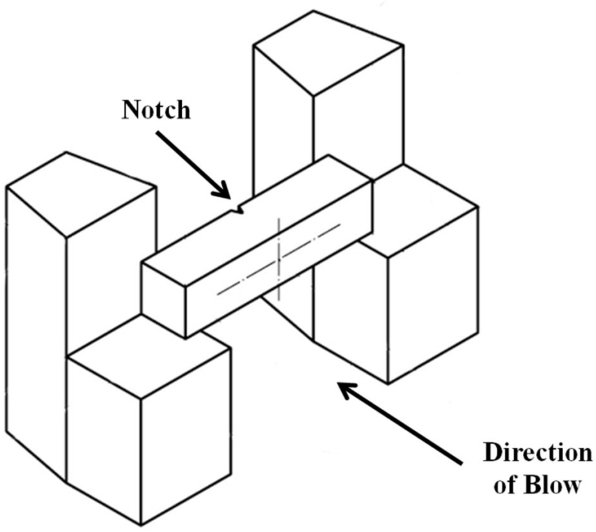


Figure 3.1: Placement of the test piece on apparatus supports

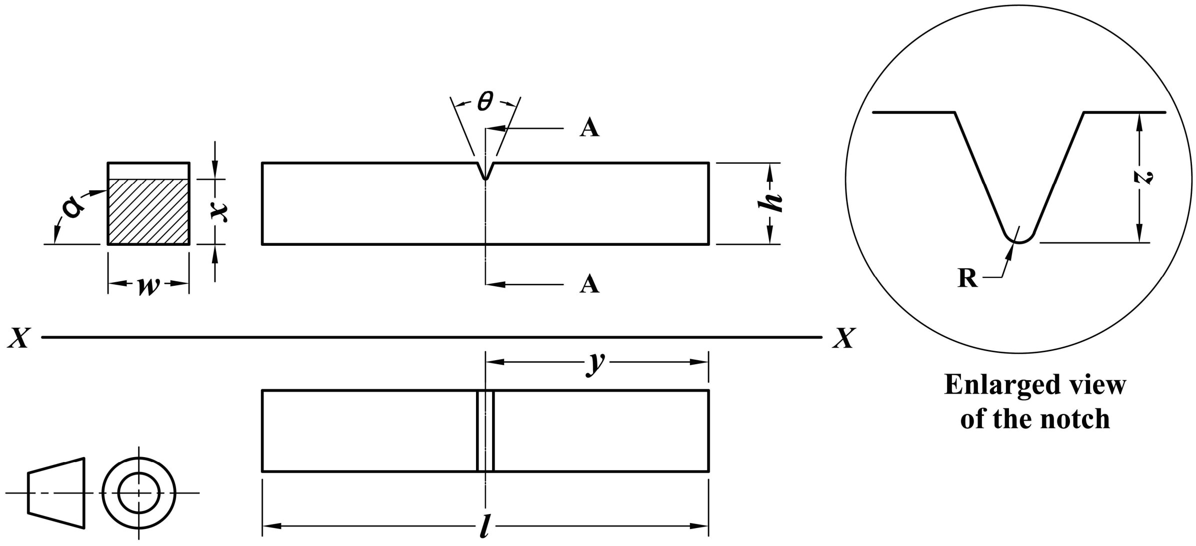


Figure 3.2: Geometry of the V-notched bar *[as per ISO 148-1:2009(E)]*

Table 3.1: Tolerances on specified test piece dimensions *[as per ISO 148-1:2009(E)]*

Designation	**Symbol used**	**Nominal Dimension**	**Machining Tolerance**
Length	l	$55\ mm$	$\pm 0.60\ mm$
Height	h	$10\ mm$	$\pm 0.075\ mm$
Width (for standard test piece)	w	$10\ mm$	$\pm 0.11\ mm$
Angle of notch	θ	$45°$	$\pm 2°$
Height below notch (height of test piece minus depth of notch)	x	$8\ mm$	$\pm 0.075\ mm$
Radius of curvature at base of notch	R	$0.25\ mm$	$\pm 0.025\ mm$
Depth of notch	z	$2\ mm$	$-$
Distance of plane of symmetry of notch from ends of test piece	y	$27.5\ mm$	$\pm 0.42\ mm$
Angle between adjacent longitudinal faces of test piece	α	$90°$	$\pm 2°$

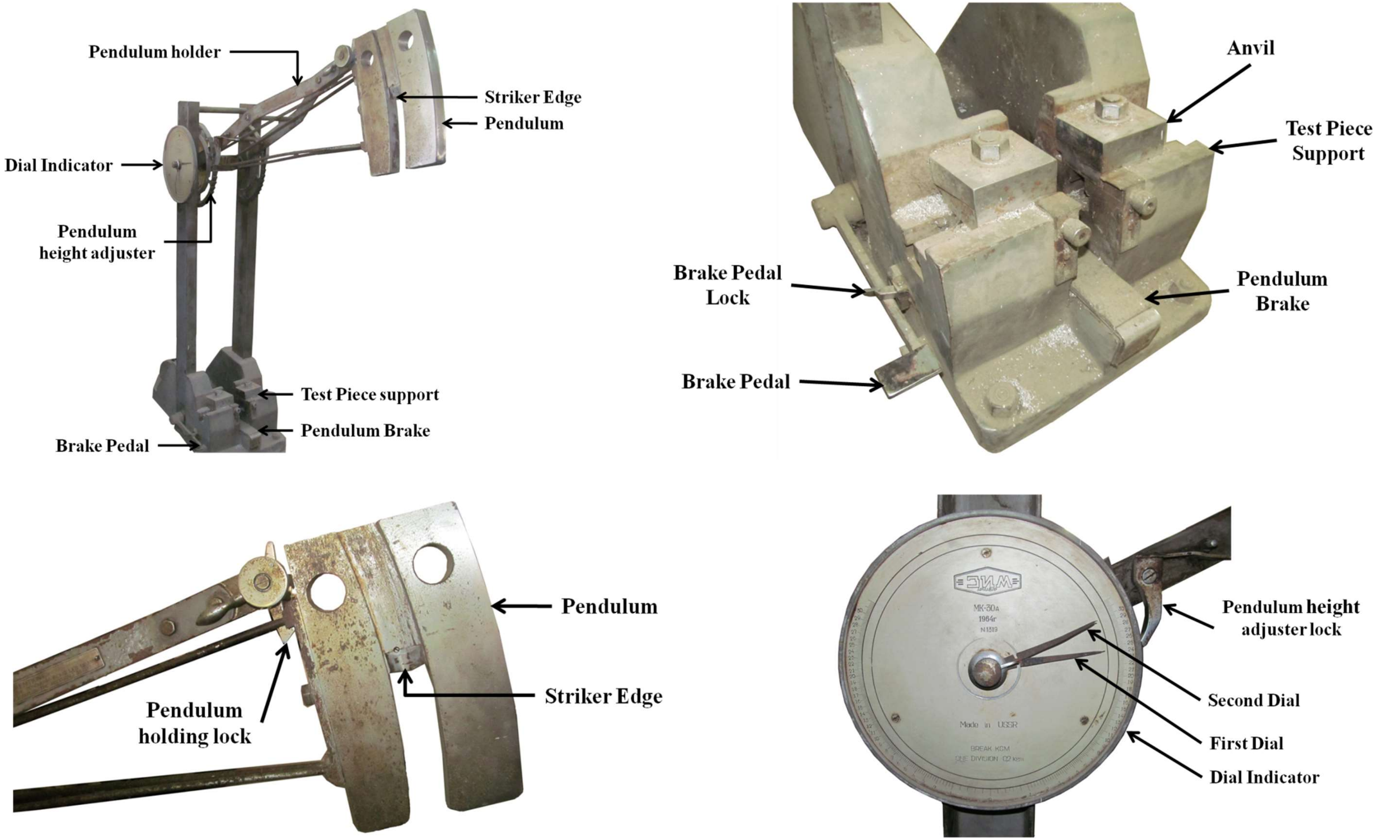


Figure 3.3: Parts of the Charpy Impact Test apparatus

REFERENCE:

- ISO 148-1:2009(E) document.

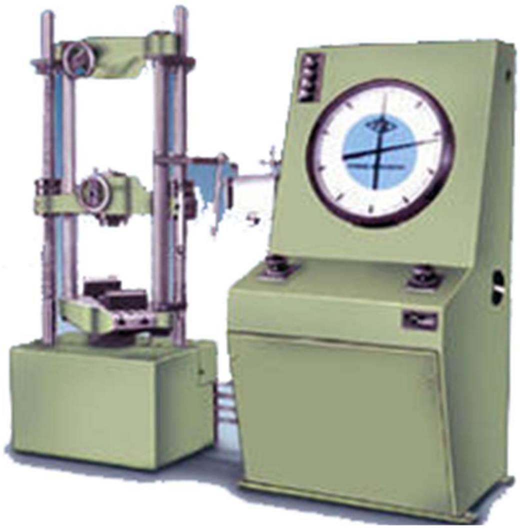
Exp. No. 3	**Title:** Charpy Pendulum Impact Test.
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check **SEAL**

Experiment No. 4

TITLE: Tension Test.

OBJECTIVE:

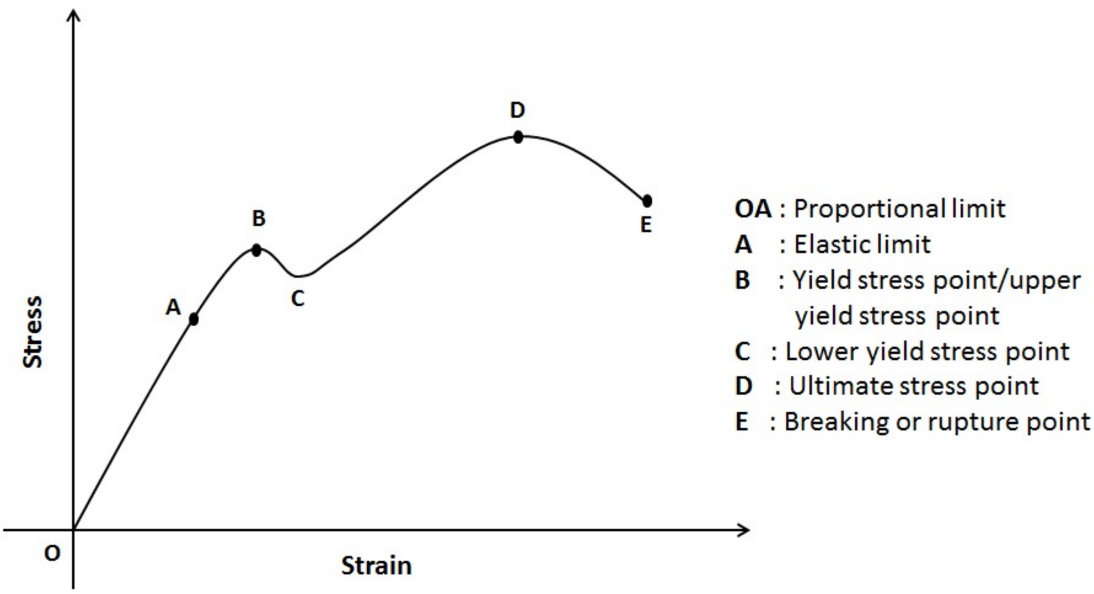


To determine the following parameters of the given specimen:

1. Elongation
2. Maximum stress
3. Breaking stress
4. % age of reduction of Area

THEORY:

Refer to the following Stress – Strain diagram for ductile material.



APPARATUS:

1. Universal Testing Machine

SPECIMEN:

Draw the dimensional sketch of the specimen.

OBSERVATION:

Sl. No.	Diameter (mm)	Average Diameter (D) (mm)	Neck Diameter (d) (mm)	Length of the specimen (L_1) (mm)	Length of the specimen after elongation (L_2) (mm)	Maximum Load (P_1) (kN)	Breaking Load (P_2) (kN)
	$D_1 =$						
	$D_2 =$						
	$D_3 =$						

RESULTS:

1. Elongation $= L_2 - L_1 =$

2. Maximum stress $P_1/D =$

3. Breaking stress $= P_2/D =$

   Therefore, % Reduction of Area $= (\pi/4)(D^2 - d^2) =$

Exp. No. 6	**Title:** Tension Test.
Name of Student:	
Roll No.:	
Date of Experiment:	
Date of Submission:	

Signature of Teacher with Date of Check

SEAL