MATERIAL TESTING LABORATORY
(18MEL37) Lab Manual
3RD Semester B. E. Mechanical

Department of Mechanical Engineering

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DEPARTMENT OF MECHANICAL ENGG

Laboratory Manual

MATERIAL TESTING LABORATORY.

Code-18MEL37

NAME	
REG.NO.	
BRANCH.	
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CONTENTS

EXP.NO.1: ROCKWELL HARDNESS TEST.

AIM: To study the Rockwell hardness test and determine the hardness number of the given specimen.

APPARATES: Rockwell hardness testing machine.

PROCEDURE:

1) Place the specimen on the anvil so that its surface will be normal to the direction of the applied load.
2) Note the type and size of the indenter.
3) Adjust the weights on the plunger according to the Rockwell scale required as shown in chart by load selection disc.
4) Keep the lever at position ‘A’..
5) Raise the anvil and test specimen by turning the hand wheel clock wise direction and so that the specimen will push the indenter and small pointer in the dial start to move.
6) Continue to raise the specimen until the small pointer comes to the set (red spot) position. This indicates that the minor load of 10kgf

is acting upon the indenter.

7) Turn the lever from position at ‘A’ to ‘B’ slowly so that the total load

is brought into action without any jerks.

8) The indenter starts to go down into the specimen and the long pointer of the dial gauge reaches a steady position when indications complete.

9) Then take back the lever to position ‘A’ slowly.

10) Read the position of the pointer on the selected scale, which gives the Rockwell hardness number. Use block or red scale as per selection of Rockwell scale.

11) Turn black the hand wheel and remove the specimen.

12) Carry out the same procedure to obtain three independent hardness determinations on each specimen.

Result:-

OBSERVATION AND TABULATION;

Material	Scale Symbol	Indenter	Total load ‘F’ (kgf)	Rockwell hardness Number (HRB or HRC
1) Mild steel.	B	1/16’’	100kgs	
2) Brass	B	1/16”	100kgs	

3) Alluminium B	1/16”	100kgs

EXP. NO.2. BRINELL HARDNESS TEST

To study the Brinell hardness teste and to determine the hardness number of the given specimen.

Apparatus: Brinell hardness tester and micrometer microscope.

Procedure:

1) Place the specimen on the anvil so that its surface will be normal to the direction of the applied load.
2) Note the type and size of the indenter.
3) Adjust the weights on the plunger according to the Brinell scale required as shown in charts by load selection disc.
4) Keep the lever at position ‘A’.
5) Raise the anvil and test specimen by turning the hand wheel clockwise sothat specimen will push the indenter and the small pointer in the dial starts to move.
6) Continue to raise the specimen until the small pointer comes to the SET (red spot) position. This indicates that the minor load of 10kgf is acting upon the indenter.

7) The indenter starts to go down into the specimen and the long pointer of the dial gauge reaches a steady position when indentations complete.
8) Then take back the lever to position ‘A’ slowly

9) Turn back the hand wheel and remove the specimen.

10) Measure the diameter d of the impression or indentation left by the ball by means of micrometer microscope.
11) Carry out the same procedure to obtain three independent hardness determinations on each specimen.

Results: Material Time Indenter Load

Mild steel	30sec 2.5mm 187.5kg
Aluminum	30sec 2.5mm 187.5kg
Brass	30sec 2.5mm 187.5kg

INDENTATION:

EXP.NO.3VICKERS HARDNESS TEST.

Aim: To study the Vicckers Hardness Tester and to determine the hardness number of the given Specimen.

Apparatus: Vickers Hardness tester.

Procedure:

1) Select the weights according to the expected hardness of specimen to be tested by turning the “Weight selection knob”. The respective figure of weight is visible on one side of knob itself.

2) Place the specimen securely on testing table.

3) Turn the hand wheel clockwise slowly so that specimen will get focused on front screen sharply. At this stage a gap of about 0.2 to 0.25mm expected between tip of Diamond indenter and top face of specimen.

4) Adjust the dwell timer for required duration of load on specimen.

5) Press start button. Keep it pressed till light inside STRAT button will be on even after release of push button. The loading cycle starts gradually through a geared motor provided with a drive cam. The loading dwell/unloading cycle is fully automatic.

6) Index indenter head to next position so that objective of optical system will be exactly over the indentation.

7) The indentation is now projected on front focusing screen. Measure diagonal of impression in both axes. Find mean value.

8) To have next test change position of specimen where hardness is to be checked. Verify from front focusing screen that is no earlier indentation hear about expected new indentation.Idex the head to original position and bring back indenter on specimen. Repeat optional from 1to7 with other given specimen.

Result :

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SKETCH

0BSERVATION AND TABULATION

Material	Load F(kg)	Diagonal length of indentation(mm)			HV=1.8544F / d
		D1	D2	Mean. d=(D1+D2)/2	
Mild steel Aluminum Brass					

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EXP.NO.4. IMPACT TEST (CHARPY)

Aim: To study the impact machine of the pendulum type and to determine the impact strength of the give specimen in the form of notched bar Charpy specimen.

Apparatus: Pendulum impact machine.

Procedure:

1). For conducting the test. Charpy stricker is to be firmly secured to the bottom of the hammer. Note the weight "W"of the pendulum and the radius 'r'its center of mass.

2). Before proceeding to the actual test, determine the frictional loss in the machine.(To determine the frictional loss, initially adjust the pointer along with pointer carrier on 300 J reading on the dial when the pendulum is hanging free vertically. Now raise the pendulum and latch in. With no specimen in the anvil, release the pendulum. Pointer will then indicate the energy loss due to friction.)

3). Lift the pendulum to its upper position and adjust the fiction pointer to make contact with the pendulum.

4). Note the initial reading on the scale if the graduation is in degrees(angle of fall á) If the scale is graduated in energy units, adjust the pointer to read the striking energy.

5). Place the specimen on the anvil such that the notch on the specimen should opposite to the direction of impact of the pendulum striker.

6). Release the pendulum to rupture the specimen.

7). Note the angle of raise of the pendulum â or the energy to rupture from the scale.

8). Stop the pendulum to swing by means of brake lever.

9). Repeat the above procedure with other specimen.

Result:-

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OBSERVATION AND TABULATION:-

(1). Length of the specimen L=…………..in mm

(2). Area of the specimen at notch A=…………..in mm

(3) .Weight of the pendulum W=…………inN

(4). Length of the pendulum r =……………mtr.

(5). Angle of fall á =……………..

(6) .Impact velocity v = √ 2gr(1-cosá)=……….

v=…………….m/sec

Material	Angle of fall β	Fracture energy from Scale “U” J(N-m)	Fracture energy U=Wr(cosâβ-cosáα) J(N-m)	Impact strength K=U/A (J/mm)

EXP.NO.5 IMPACT TEST (IZOD)

AIM: To study the impact machine of the pendulum type and to determine the impact strength of the given specimen in the form of notched bar Izod specimen.

APPARATUS: Pendulum type impact machine.

PROCEDURE:

1) For conducting the test.Izod sticker is to be firmly secured to the bottom of the hammer. Note the weight 'W' of the pendulum and the radius 'r' its center of mass.

2). Before proceeding to the actual test. determine the frictional loss in the machine.(To determine the frictional loss, initially adjust the pointer along with pointer carrier on 168 J reading on the dial when the pendulum is hanging free vertically. Now raise the pendulum and lock to the lachet.No specimen in the anvil, so release the pendulum. Pointer indicates the energy loss due to friction).

3). Lift the pendulum to its upper poison and adjust the friction pointer to make contact with the pendulum.

4). Note the initial reading on the scale if the graduation is in degree (angle of fall á)the scale is in energy units, adjust the pointer to read the striking energy.

5). Place the specimen on anvil the notch on the specimen should face the pendulum striker and clamp it firmly.

6). Release the pendulum to rupture the specimen.

7). Note the angle of raise â or the energy rupture from the scale.

8).Stop the pendulum to swing by means of brake lever.

9).Repeat the above procedure with other specimen.

RESULT:

…………………………………….

……………………………………

…………………………………….

……………………………………

OBSERVATION AND TABULATION:

1). Length of the specimen . . L=…………………..mm

2). Area of the specimen at notch. A=…………………..mm

3). Weight of the pendulum. W=………………….N

4). Length of the pendulum. r = …………………m

5). Angle of fall. α=…………………..

6). Impact velocity. . $v=\sqrt{2gr(1-\cos\alpha)}$

v=…………………m/sec.

material	Angle of fall β	Fracture energy from scale 'U' J(N-m)	Fracture energy U=W r(cos β-cosα)	Impact strength K=U/AL J/mm

SKETCH:.....

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EXP.NO.6.TENSION TEST (TENSILE TEST)

AIM: To determine the srength and several properties of the ductile steel to observe the behavier of the material under load,and to study the fracture and thus determine the followings.

1.Elastic strength in tension; a)praporsional limit, b) yield point
2.Modulus of elasticity.
3.Plastic strength: a) ultimate strength. b) breaking stress.
4.Ductility: a) % of reduction in area. b) %of elongation.
5.Modulus of resilience.
6.Modulus of toughness.

APPARATUS: Universal testing machine,extensometer,vernier calliper and scal.

INITIAL ADUJUSTMENT: Before testing adjust the measuring gauge according to capacity of the test.

PROCEDURE:

1. Measure the diameter of the specimen at several section with a micrometer to obtain amean value.

2. The gauge lenth L0 is marked off by means of center punch and is measured.
3. finaly grip one end of the specimen in the fixed head of the testing machine such that the punch marks face the front of the machine.
4. Mount the extensometer centrally on the specimen the fixing screws being located in the punch marks.
5. Remove the locking bar of the extensometer and set the zero.
6. Grip the other end of the specimen.applied load at slow speed and amke simultaneous observations of load'F' and exetensometer reading L.
7. When the increment of load leads to disproportionate extension replace the locking bars and remove the extensometer.
8. Continue to load the specimen taking the extensions by means of graduated scale.
9. Record yield point Fy maximum load Fmax and the'load at fracture Fb.
10. Remove the brocken specimen from the machine.observe the location and character of the fracture and measure the diameter at neck df.place the two parts togehter and measure the final gauge length Lf.
12. plot stress and strain diagram for the test.

OBSERVATION AND TABULATION *

Material =MILD STEEL.

Initial gauge length Lo =.................

Initial diameter do =.................

Original area Ao =.π(d2)

Maximum load Fmax=..........N

Final gauge length Lf =............N

Final diameter df =..........mm

Final area Af = π d2........mm2

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4

Ultimate tensile strength = Fmax-----------N/mm2

Ao

% of Elongation De = Lf-Lo * 100
____
Lo

% of Reduction in area Do = Ao – Af *100
____
Ao

Modulus of resilience U = __________ N/mm2
2E

Modulus of toughness To= (Lf –Lo)__________mm2
____________________-
Lo

Straight line portion of the graph . Slope E =...............N/mm2

* TABULATIONS *

Sl no	Load F in N	Deformation dL (mm)	Stress = F / Ao	Strain E=dL / Lo	Young Modulus E =

RESULT :

* Youngs Modulus E = ...N/mm2

* % of Reduction in Area. $Da = \frac{Ao - Af}{Ao} * 100$ ....%

* % of Elongation $De = \frac{Lf - Lo}{Lo} * 100$ ....%

* Modulus of resilience. $U = \frac{\_\_\_\_}{2E}$ N/mm2

SKETCH*____________________

EXP:NO 07 .COMPRESION TEST (UNIVERSAL TESTING MACHINE)

AIM: To study the behavier of the given material under the copressive loading and to determine the following properties.

(1) Proportional limit

(2) Modulus of elosticity

(3) Compressive strength

(4) % of contraction

(5) % of increase in area

(6) Initial tangent modulus of elasticity

Apparatus :- Universal testing machine. Compressometer . Calliper . and scale.
Initial adjustment :- Before testing adjust the measuring gauge according to capacity of the test.

PROCEDURE.*

1.) Measure the diameter of the specimen at several section with a micrometer to obtain a mean value.

2.) The initial length Lo is measured.

3.) Place the specimen between the table and the lower cross head of the machine.

4) Mount the copressometer to read at zero.

5) Apply load at slow speed and make simultaneous. observations of load F and compressometer reading Δ L.

6) Continue the load the specimen taking the copression by means of graduated scale.

7) Record yield point Fy. Maximum load in case of ductile material.and Fmax or the load at fracture Fb in case of brittle material.

8) Remove the broken specimen from the machine.observe the location and character of the fractur and measure the final diameter df and final length Lf.

9) Plot stress and strain diagram for the test.

RESULT ;

Proportional limit εp =---------------N/mm^2

Moduluse of elosticity E=------------N/mm^2

Compressive strength =------------N/mm^2

% of contraction (D_2) =-------------%

% of increase in area (D_A) =-----------%

Initial tangent modulus of Elosticity =-------------N/mm^2

OBSERVATION AND TABULATION

1. Material ;MILD STEEL
2. Initial gauge length. L_0 =-----------mm

3. Initial diameter d_0 =-----------mm
4. Original area $A_0 = \frac{\Pi d^2}{4}$ =---------mm^2
5. Load at proportianal limit F_p =------------N
6. Maximum load F_{max} =------------------N
7. Final gauge length L_f =---------------mm
8. Final diameter d_f =------------mm
9. Final area $A_F = \frac{\Pi d^2}{4}$ =----------mm^2
10. Proportional limit $\sigma_p = \frac{F_p}{A_o}$ =----------N/mm^2
11. Copressive strength = $\frac{F_{max}}{A_0}$ =- --------N/mm^2
12. % of contraction at fracter $D_a = \frac{A_f - A_o}{A_o} * 100$
13. % of increase in area $D_A = \frac{A_f - A_o}{A_o} * 100$ =....................%
14. Slope of straight line praportion of the graph. E =------------N/mm^2.

TABULATION ;

SL NO	LOAD IN KG'S	Deformation .ΔL(mm)	Stress (σ)=$\frac{F}{A_O}$ (N/mm)	Strain (ξ)=$\frac{\delta L}{L_o}$	Young's madulus E =$\frac{\sigma}{\xi}$ N/mm^2	

1 2 TO 21 22						

COMPRESSION TEST GRAPH ;

COPRESSION TEST SPECIMEN ;

- END--------

Exp no 8. SHEARE TEST .

(UNIVERSAL TESTING MACHINE)

AIM :To determaine the ultimate shear stress of the given specimen in SINGLE and DOUDLE SHEAR.

APPARATUS : UNIVERSAL TESTING MACHINE and MICROMETER VERNIER CALLIPER.

PROCEDURE :

1) The average diameter ‘d’ of the specimen with a micrometer and vernier calliper

measured .

2) For single shear test fix the specimen .
3) Apply the load slowly at right angles to the axis of the piece through the central block .
4) Note the fracture energy load .
5) Absereve the structure of the fracture surface .
6) Report the above test by fixing the specimen .

$$\text{ULTIMATE SHEAR STRENGTH} = Z_U = \frac{F}{A}$$

For single shear 'F'is fracture load.

A = cross sectional area .

$$\text{For Double shear} = Z_u = \frac{F}{2A} \quad \text{where } A = \frac{\Pi d^2}{4}$$

OBSERVATION AND TABULATION ;

Material	Types of shear	Diameter(d)mm	Fracture load F(N)	Area $A= \frac{\Pi d^2}{4}$ (mm^2)	Ultimateshear strength in(N/mm^2)
Mildsteel	SINGLE SHEAR				
Mildsteel	DOUBLE SHEAR				

CALCULATIONS ;

1). For SINGLE SHEAR . $Z_U = \frac{F}{A}$ Where ....d= Diameter of the given specimen

$$A = \frac{\Pi d^2}{4}$$

Ultimate shear stress , Z_U =...............N/mm^2

2) . For DOUBLE SHEAR , $Z_U = \frac{F}{2A}$

Where....... d = Diameter of the given specimen .

$$A = \frac{\Pi d^2}{4}$$

Ultimate shear sress ,Z_U =............N/mm^2

SKETCH FOR SINGLE SHEAR SKETCH FOR DOUBLE SHEAR .

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******************** END ***********************

EXP NO- 09 * BENDING TEST *****

(UNIVERSAL TESTING MACHINE)

AIM ;- To study the behavier of the given under bending and to determine the following properties .

(1) ELASTIC STRENGTH .
(2) MODULUS OF ELOSTICITY
(3) MODULUS OF RESILIENCE
(4) MODULUS OF FRACTURE
(5) MODULUS OF TOUGHNESS

APPARATUS :-

The universal testing machine.scale and deflectometer .

INITIAL ADJUSTMENTS :-

Before testing adjust the measuring gauge according to capacity of the test.

PROCEDURE :-

1) Measure the cross sectional dimensions.
2) Mark the span length ‘L’ symetrical with the length of the specimen.
3) Firmly place the specimen over the support.
4) Attach the deflectometer at the center of the span and adjust zeero.
5) Apply the load at the center of the span and at slow speed.
6) Record the load at breaking point ‘F_Y’ (Fracture & deflection).
7) Plot a load deflection graph or diagram . for the test in accordinate with general instruction & coplete all properties called fir the given specimen using appropriate formula.
8) Repeat the above test on the specimen.

RESULT :-

1) Elastic strength of the given M.S specimen =....................
2) Modulus of Elosticity. E =..............N/mm^2.
3) Modulus of Resilience U =............mm/mm^3.
4) Modulus of rapture of the given M.S specimen is σ_u =..................Nmm/mm^3.
5) Toughtness of the given M.S specimen is T_u =................Nmm/mm^3.

OBSERVATION AND TABULATION :

1) Material = Mild steel
2) Span length L =..........mm.
3) Breadth B =..............mm.
4) Depth H =............mm.
5) Distance $C = \frac{H}{L}$ =.........mm.
6) Load at yield point. F_y =............mm.
7) Deflection at yield point Y_y =.........mm.

9) Maximum load. F_f =...........N.
10) Maximum deflection Y_f =.........mm.
11) Area. A = BH........mm^2.
12) Moment of inertia $I = \frac{BH^3}{12}$ =...........mm^2.
13) Bending moment at yield point $M_{by} = \frac{F_Y L}{4}$ = ...N/mm.

14) Elastic strength $\sigma_y = \frac{M_Y C}{I}$ =............N/mm^2.
15) Modulus of resilience $U = \frac{F_Y Y_Y}{2AL}$ = ...N/mm^2.

_ 16) Modulus of Bending moment $M_{bu} = \frac{F_f L}{4}$ = ...N/mm.

17) Modulus of rapture $\sigma_u = \frac{M_{bu} C}{I}$ =..................N/mm^2.

18) Modulus of toughness $T_o = \frac{2F_f Y_f}{3AL}$ = ...N/mm^2.

19) Modulus of elosticity $E = \frac{FL^3}{48YI} = \frac{L^3}{48I}$ X slope of the load deflection.

TABULATION:

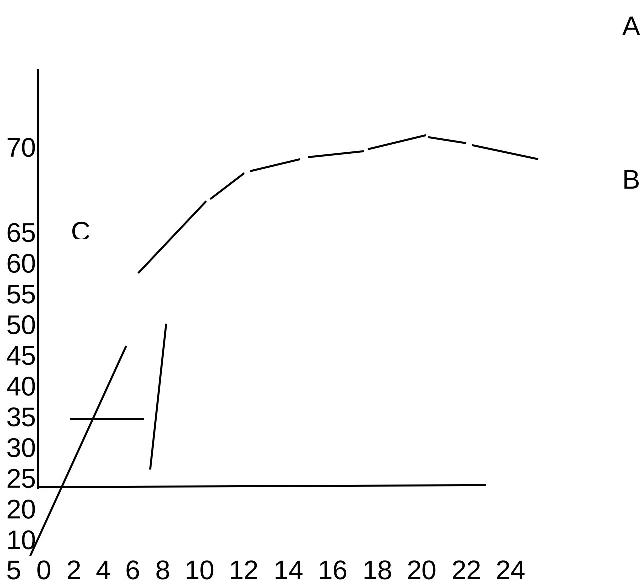
Load inKN	Deflection in Y (mm)	Modulus of elosticity $E = \frac{FL^3}{48YI}$ N/mm^2	Load in N	Deflection in Y mm	Modulus of Elosticity $E= \frac{FL^3}{48YI}$ 1) N/mm^3
1 2 3 4					

5					
6					
7					
8					
9					
10					
11					
12					
13					

Material-Mildsteel
Length =300mm
Bredth =25.28mm
F_p =200KN
Height =25.40mm

Area =BxH =.............mm^2 F =$\frac{BH^3}{12}$

GRAPH:-



scale :-
x-axis 1cm =2mm
y-axis 1cm =5KN

Slope = $\frac{AB}{BC}$ = $\frac{F}{Y}$ =---------------N

E = $\frac{L}{48I}$ X slope =-------------N/m

*****************END******************

EXP NO –10 **<u>* MICROSTRUCTURE EXAMINATION *</u>**

AIM :- To study the microstructure of the given specimen and to determaine the grain size.

APPARATUS :- Hand press file.emery paper of various grade.Rotary polishing machine and metallargical microscop .

<u>Preparation of specimen for microscopical examination</u> :

1. <u>Selection of specimen :</u> Aspecimen is 10mm dia or square and length 10mm is to be cut from the metal.
2. <u>Grinding :</u> Cutting mark have been ground out and washed .
3. <u>Fine grinding :</u> It is carried out on water proof emery papers of 220,320,400, and 600.
4. <u>polishing :</u> It is to remove the fine scratches on surface.
5. <u>Etching :</u> To make its structure apparent under the microscope.

Type of Etchent	**Composition**	**Characterstic and use**
Nital	2cc nitric acid & 98cc ethanol	Iron & steel
Picral	4gm picric acid & 96cc ethanal	Cast iron
Acid ammonium peroxi – di- sulphate	Ammonium peroxo-di-sulpate 80cc water	Staineless steel
Dilute hydrofloric acid	0.5cc hydrofloric acid.99.5cc alchol	Alluminium
Ammonium hydrogen peroxide	50cc ammonium hydroxide 20-50cc hydrogen peroxide 50cc water.	Bronze.

PROCEDURE :

1. Prepare the given specimen as explained above etch it.
2. Mount the specimen on the callibrated microscope slide such that the surface is normal to the axis of the instrument.
3. Record the objective magnification & eye piece magnification to detemaine the total magnification.
4. Focus the surface of the specimen using coarse adjustment & then by the adjustment.
5. Above the microsructure & record it.
6. Identify the material by comparing the microstructure with the standard microsructure.
7. Repeat the same for the other specimen.

FIGURES :

BRASS COPPER

BRONZ ALLUMINIUM

MILD STEEL CAST IRON

****************************END*****************************

EXP NO –11 **<u>* PIN – ON DISK / WEAR TEST *</u>**

AIM :-To determaine wear characterstic of diffrent metal parts.

APPARATUS :-Pin on disk wear testing machine.electronic weighting machine.

PROCEDURE:-

1) Select pin material & clean it throughly.
2) Weight it in electronic weighing machine and note down weight in grams (G_1 grams).
3) Fix load assembly at desired distence from the central axis (Rmm).

4) Start the motor &with varying speed of disc.

5) Put weight on plat form Wkg& bring entire load assemby down & place it on

6) rotating disc.

7) Note down time of start & allow it to rotate with rubbing of pin against disc.

8) After sometims stop the motor & remove pin from the chuck.

9) Note down once again weight of the pin in grams (G_2 grms)

10) Repeat experiment for diffrent weights. Pin.speed & distance.

RESULT :-

1) 300rpm at 5kg the wear rate is—**0.55×10^{-5} gms**.-------------------
2) For 400 rpm at 5kg the wear rate **is 0.62×10^{-5} gms**.
3) For 200 rpm at 8 kg the wear rate is **1.67×10^{-5} gms**.
4) For 300 rpm at 8 kg the wear rate is **0.837×10^{-5} gms**

WEAR TEST FORMULA

Mass of material removes $\Delta G = G_1 - G_2$ =--------------------------gms.

Sliding distance $S = 2 \pi R N (t_2 - t_1)$ =----------------mm.

Wear rate . $K = \frac{\Delta G}{S}$ =--------------gms/m.

TABULAR COLUMN:-

SL NO	Pin type	Load 'W'kg	Distance 'R' mm	Speed 'N' rpm	Time in minutes Start 't_1'	Finish 't_2'	Weeight of pin Before test 'G_1'gms	After test 'G_2'gms
__1 2	Alluminium	5	95	300	0	20		

3				400	0	20		
4								
				200	0	20		
	Alluminium	8	95					
				300	0	20		

CALCULATIONS –

For 300 rpm at 5 kg :-

$\Delta G = G_1 - G_2$ =--------------------

$S = 2 \Pi R N (t_2 - t_1)$
=--------------------

$K = \frac{\Delta G}{S}$

=--------------g/m

For 400 rpm at 5kg :-

For 200 rpm at 8kg :-

For 300 rpm at 8 kg :-

**************************** E N D **********************

EXP NO –12- *** FATIGUE   TEST ***

AIM :- To check the fatigue strength of the given specimen .

APPARATUS :-

PROCEDURE:-

1) Give the electrical connection to the machine & lift the load in pan by hand & switch on the machine by direction of rotation of the machine.

2) Direction or rotation of shaft should be clockwise while looking shaft from the left
3) side of the machine.
4) Insert the specimen on either side & tighed with the collet.
5) Also see that the end of specimen is in flush with bearing support. This ensures the
6) effective length of cantilever load in to the 75mm.
7) Now lower the loading pan, so that the weigth of the pan acts on specimen through
8) bearing.
9) Now switch on the machine &observe the reading.
10) When specimen fails that particular counter cycle stops counting.
11) Take down the readings & tabulates the result.

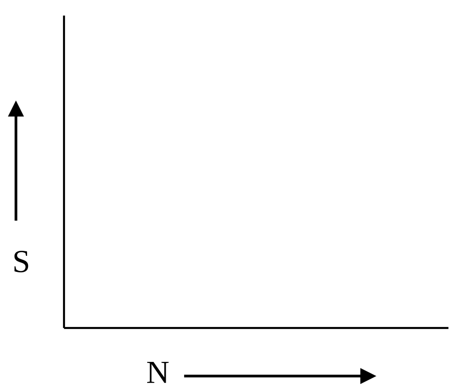
OBSERVATION AND TABULATION:-

Formula :- $F = (2P + 1.4)$

$$M = F \times L$$

$$\Sigma_b = \frac{M}{Z} \quad \text{Where} \quad Z = \frac{\pi d^3}{32}$$

Graph :-



Tabular column :-

Sl no	Load applied in kg (P)	Stress 'S' N/mm^2	No of cycles to failure (N)

1	8		
2	10		
3	12		

Calculations :-

1), $F = (2P + 1.4)$
=
=

2), $M = F \times L$
=
=

3), $Z = \frac{\pi d^3}{32}$

4), $\sigma_b = \frac{M}{Z}$
=
=

*********************** THE END ***************************