GRAPHING TECHNIQUES FOR MATERIALS LABORATORY USING EXCEL

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Graphing Techniques for Materials Laboratory
Using Excel

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KEY WORDS: Spring rate, stress concentration, endurance limit, column buckling, linear regression, slope-intercept, logarithmic graphing.

PREREQUISITE KNOWLEDGE: Students should have a course in computer literacy and some knowledge in strength of materials including stress-strain, cyclic loading, and column buckling.

OBJECTIVES: To introduce the use of Microsoft Excel spreadsheet for data reduction and evaluation of experimental results. This paper is intended to serve as a tutorial with a number of sample experiments on a strength of materials course.

INTRODUCTION
Engineering technology curricula stress hands on training and laboratory practices in most of the technical courses. Laboratory reports should include analytical as well as graphical evaluation of experimental data. Experience shows that many students neither have the mathematical background nor the expertise for graphing.

This paper briefly describes the procedure and data obtained from a number of experiments such as spring rate, stress concentration, endurance limit, and column buckling for a variety of materials. Then with a brief introduction to Microsoft Excel the author explains the techniques used for linear regression and logarithmic graphing.

GENERAL GRAPHING PROCEDURE
The concepts one needs to know on Microsoft Excel worksheet are shown in figure 1. Arrange the data such that all the X values are in the first column of the data area to be selected for graphing. The first row of data is usually column headings and is displayed in the legend. The second column is the Y values for the first curve and the third column is the Y values for the second curve and so on.

Highlight the data to be graphed and select the type of graph by clicking on FILE _ NEW _ CHART _ OK. A bar graph is displayed as default. Now GALLERY shows up in the menu bar. Select GALLERY _ X (select an appropriate number for the desired type of graph for X)

To add legend highlight the data table including the legend and click on the CHART menu when a dialog box is displayed. Click on ADD LEGEND.

To add text for title and axes click on CHART _ ATTACH TEXT _ CHART TITLE _ OK. A set of squares appear on the graph. Type the title,
ENTER, and then click the mouse with the arrow on the graph. Go back to chart menu and click on ATTACH TEXT and repeat the same procedure for CATEGORY AXIS and VALUE AXIS.

Entering data, graphing techniques and printing of your work are explained step by step with the help of experimental data in the following. Experiments are selected to give readers a general overview of mostly used graphing assignments.

EXPERIMENTS

Spring Rate:
Spring rate is the amount of load that is required to compress the spring per unit of deflection. The data table shows the force(lb) used to compress a spring causing a reduction in length(in) recorded as deflection.

This is an example of a set of curves including legend, title, and axes. This graph also demonstrates the linear regression technique using the LINEST function.

Worksheet 1. Spring Rate:
Click the mouse on FILE _ NEW - WORKSHEET _ OK
Enter title at the top, pick cell C3 and highlight C3:D3 with the mouse, change the font style, font type, and size as follows:
FORMAT _ FONT _ BOLD _ SIZE 10 _ OK

Create column headings
Select cell and type text using appropriate font settings.

Enter data:
For the graph start column with zeros. Type the load data in A6 to A11 and spring A deflection data in B6 to B11.

To change the precision of the displayed value highlight the column, click FORMAT _ NUMBER, position the cursor at the CODE bar and type in 0.000 _ OK.

Slope-Intercept Formula / Linear Regression:

Assign names to columns
Select the cell and highlight the selected column (do not include zeros), click
Click on FORMULA _ DEFINE NAME _ type in name (example: A for column A) _ OK

Create title for slope-intercept in the cells as shown:
To enter the slope-intercept function LINEST for spring A highlight the two adjacent cells below the slope intercept titles, type the formula for spring A exactly as
=LINEST(B,A) where B is the name of the second column and A is the name of the first column as
defined earlier. Press and hold CONTROL + SHIFT and press ENTER. The slope and intercept values are now displayed in the selected cells.

Linear Regression:
The linear regression (L.R.) column for spring A is created by entering the slope - intercept formula in cell C6 as =$A$14*A6+$B$14 _ ENTER, once entered click EDIT _ COPY highlight cells C7:C11 _ ENTER. (C7:C11 means cell C7 through cell C11)

Repeat for spring B using column E for load, column F for deflection, and column G for slope-intercept formula.

Graphing Spring Rate (figure 2):
Highlight A5:C11, press and hold CONTROL and highlight F5:G11 Select FILE _ NEW _ CHART _ OK, bar graph is displayed, click on GALLERY, pick #5 _ OK.

at CHART menu click on ADD LEGEND
at CHART menu click on ATTACH TEXT _ CHART TITLE _ OK
type title SPRING RATE _ ENTER, click mouse

click on CHART _ ATTACH TEXT _ CATEGORY AXIS _ OK
type LOAD(lb), click mouse

click on CHART _ ATTACH TEXT _ VALUE AXIS _ OK
type DEFLECTION(in) _ ENTER, click mouse

click on CHART _ ADD ARROWS, position mouse at the arrow ends, press and hold and move to the desired location

type SPRING A for the first spring
repeat for spring B

Stress Concentration
The presence of shoulders, grooves, keyways, threads, or any type of discontinuities in machine elements results in modification of simple stress distribution.

In this experiment force is applied at the end of a cantilever beam with a hole creating stress proportional to the deflection. Purpose of this experiment is to measure stress level at various distances from the hole. Strain gages are installed at the desired locations on the beam for stress readings. The experimental data is displayed in the given table.

Worksheet 2. Stress Concentration:
Type STRESS CONCENTRATION in B2 _ ENTER
type Gage #1, Gage #2, Gage #3, and Gage #4 in B4, C4, D4, and E4
type data table as given in A5:E9
Graphing Stress Concentration (figure 3):

highlight A4:E9

click on FILE NEW CHART OK

click on GALLERY LINE 5 OK

click on CHART ADD LEGEND_OK

click on CHART ATTACH TEXT _ CHART TITLE_OK, click
type STRESS CONCENTRATION _ ENTER, click

click on CHART ATTACH TEXT _ CATEGORY AXIS_OK

type DEFLECTION(in) _ ENTER, click

click on CHART ATTACH TEXT _ VALUE AXIS_OK

type STRESS(psi) _ ENTER, click

Printing:

click on FILE PRINTER SET UP

click on SET UP _ LANDSCAPE _ NLQ _ OK_OK

click on FILE PRINT PREVIEW_OK

click on ZOOM for close observation

click on PRINT

Endurance Limit:

Endurance limit is a material property expressed in terms of stress(psi) that can be endured during cyclic loading regardless of the number of applied cycles. This stress value is also called the fatigue limit.

In this experiment a 1/4" diameter grooved shaft is rotated under load till failure. The data table shows the groove distances from the loading point X, Groove diameter d, Load plus the weight of the fixture P, Accumulated number of cycles N, and the stress S.

Worksheet 3. Endurance Limit:

Type in the worksheet as shown, calculate the stress values using P, d, X, and Kt (=1).

Select cell E24

type formula for stress $S = \frac{32 \times P \times X}{(3.14 \times d \times d \times d)}$ in the worksheet as

$=32 \times C24 \times A24/(3.14 \times B24 \times B24 \times B24)$ and click on E24,

stress value is displayed in E24

select E24 COPY, highlight E25:E29 ENTER, stress values are displayed in column E.

Graphing Endurance Limit (figure 4):

highlight D23:E28

FILE NEW CHART OK

GALLERY SCATTER 5 OK

Enter necessary texts for the graph and print.
Column Buckling

Long columns and the more slender short columns usually fail by buckling when critical load is reached. In this experiment the critical load for 1/4" diameter and 12", 16", 20", and 24" long rods is determined.

Worksheet 4. Column Buckling:
Type the title COLUMN BUCKLING DATA SHEET in B1
click on FORMAT _ FONT _ HELV BOLD _ OK
type EXPERIMENTAL in B2
type the data table exactly as shown.

If you highlight B3:E6 column B is considered as the category axis and if you highlight A3:E6 column A serves as legend with row 3 as category axis.

highlight A3:E3
click on FORMAT _ BORDER _ SHADE _ OUTLINE _ OK, click

Graphing Column Buckling (figure 5):

highlight A3:E6
click on FILE _ NEW _ CHART _ OK
click on GALLERY _ LINE _ 6 _ OK
click on CHART _ ADD LEGEND _ OK
click on CHART _ ATTACH TEXT _ CHART TITLE _ OK
type COLUMN BUCKLING _ ENTER, click
click on CHART _ ATTACH TEXT _ CATEGORY AXIS _ OK
type LENGTH(in) _ ENTER, click
click on CHART _ ATTACH TEXT _ VALUE AXIS _ OK
type LOAD(lb) _ ENTER, click

Follow the previous instruction for printing.

REFERENCES:

Concepts You Need to Know

Figure 1
### Worksheet 1. Springs Rate

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
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</tbody>
</table>

**SPRING RATE**

<table>
<thead>
<tr>
<th>Load (lb)</th>
<th>Deflection (in) L.R. A</th>
<th>Deflection (in) L.R. B</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0.085</td>
<td>0.085</td>
</tr>
<tr>
<td>200</td>
<td>0.185</td>
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<tr>
<td>300</td>
<td>0.285</td>
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<tr>
<td>400</td>
<td>0.384</td>
<td>0.384</td>
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<tr>
<td>500</td>
<td>0.480</td>
<td>0.480</td>
</tr>
</tbody>
</table>

**Figure 2. Spring Rate**

- Deflection (in)
- L.R. A
- Deflection (in)
- L.R. B

### Worksheet 2. Stress Concentration

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
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<th>D</th>
<th>E</th>
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</table>

**Stress Concentration**

<table>
<thead>
<tr>
<th>Gage #1</th>
<th>Gage #2</th>
<th>Gage #3</th>
<th>Gage #4</th>
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<tbody>
<tr>
<td>0.1</td>
<td>3730</td>
<td>2900</td>
<td>2870</td>
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<tr>
<td>0.2</td>
<td>1130</td>
<td>5930</td>
<td>5380</td>
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<tr>
<td>0.3</td>
<td>15120</td>
<td>12010</td>
<td>10840</td>
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<tr>
<td>0.4</td>
<td>3730</td>
<td>2900</td>
<td>2870</td>
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</tbody>
</table>

**Figure 3. Stress Concentration**

- Gage #1
- Gage #2
- Gage #3
- Gage #4
Worksheet 3: Endurance Limit

<p>| | | | | |</p>
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<tbody>
<tr>
<td>X</td>
<td>d</td>
<td>P</td>
<td>N</td>
<td>S</td>
</tr>
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</table>

### ALUMINUM

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<td>5.80916</td>
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### BRASS

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<td>5.3021</td>
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<td>16</td>
<td>18.1875</td>
<td>0.3</td>
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<td>17</td>
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<td>0.298</td>
<td>5.3021</td>
<td>36871</td>
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<td>0.301</td>
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<td>19</td>
<td>10.6875</td>
<td>0.299</td>
<td>5.3021</td>
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### STEEL

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<td>9.28</td>
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</table>

**Figure 4. Endurance Limit for Aluminum**

Stress (psi)

Cycles

**Endurance Limit for Brass**

Stress (psi)

Cycles

**Endurance Limit for Steel**

Stress (psi)

Cycles
<table>
<thead>
<tr>
<th></th>
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<th>B</th>
<th>C</th>
<th>D</th>
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<td>16</td>
<td>20</td>
<td>24</td>
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<td>220</td>
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<tr>
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<td>62</td>
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<td>35</td>
</tr>
<tr>
<td>6</td>
<td>Brass</td>
<td>95</td>
<td>70</td>
<td>45</td>
<td>30</td>
</tr>
</tbody>
</table>

**Figure 5. Column Buckling**

![Graph showing load (lb) vs. length (in) for Steel, Aluminum, and Brass materials.](image)

- **Steel**
- **Aluminum**
- **Brass**