8.10:

An article by J. J. Pignatiello Jr. and J. S. Ramberg in the *Journal of Quality Technology* Vol. 17, 1985, pp. 198-206) describes the use of a replicated fractional factorial to investigate the effect of five factors on the free height of leaf springs used in an automotive application. The factors are A = furnace temperature, B = heating time, C = transfer time. D = hold down time, and E = quench oil temperature. The data are shown below:

Table : 8.10 Data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Furnace Temp | Heating Time | Transfer Time | Hold Time | Quench Temp | Free Height |
| 1 | 1 | 1 | 1 | 1 | -1 | 7.81 |
| 2 | 1 | 1 | -1 | -1 | 1 | 7.56 |
| 3 | 1 | -1 | -1 | 1 | 1 | 7.88 |
| 4 | -1 | 1 | -1 | 1 | -1 | 7.5 |
| 5 | -1 | -1 | -1 | -1 | 1 | 7.5 |
| 6 | -1 | 1 | -1 | 1 | -1 | 7.56 |
| 7 | -1 | 1 | 1 | -1 | -1 | 7.56 |
| 8 | -1 | -1 | 1 | 1 | -1 | 7.88 |
| 9 | -1 | -1 | -1 | -1 | 1 | 7.25 |
| 10 | -1 | 1 | -1 | 1 | 1 | 7.5 |
| 11 | 1 | 1 | -1 | -1 | -1 | 7.56 |
| 12 | 1 | -1 | 1 | -1 | -1 | 8.06 |
| 13 | -1 | 1 | -1 | 1 | 1 | 7.5 |
| 14 | -1 | -1 | -1 | -1 | -1 | 7.81 |
| 15 | 1 | -1 | 1 | -1 | 1 | 7.62 |
| 16 | -1 | 1 | -1 | 1 | -1 | 7.5 |
| 17 | -1 | 1 | -1 | 1 | 1 | 7.56 |
| 18 | 1 | -1 | -1 | 1 | 1 | 7.88 |
| 19 | -1 | 1 | 1 | -1 | 1 | 7.25 |
| 20 | 1 | -1 | 1 | -1 | -1 | 7.69 |
| 21 | 1 | -1 | 1 | -1 | 1 | 7.56 |
| 22 | -1 | 1 | 1 | -1 | -1 | 7.44 |
| 23 | 1 | -1 | -1 | 1 | 1 | 7.44 |
| 24 | 1 | 1 | -1 | -1 | -1 | 7.59 |
| 25 | 1 | 1 | -1 | -1 | 1 | 7.63 |
| 26 | -1 | -1 | 1 | 1 | -1 | 7.54 |
| 27 | -1 | 1 | 1 | -1 | -1 | 7.52 |
| 28 | -1 | 1 | 1 | -1 | 1 | 7.18 |
| 29 | -1 | -1 | -1 | -1 | -1 | 7.78 |
| 30 | 1 | -1 | -1 | 1 | -1 | 7.88 |
| 31 | 1 | 1 | 1 | 1 | 1 | 7.5 |
| 32 | 1 | 1 | 1 | 1 | 1 | 7.81 |
| 33 | -1 | -1 | 1 | 1 | -1 | 8 |
| 34 | 1 | 1 | -1 | -1 | -1 | 7.75 |
| 35 | 1 | -1 | -1 | 1 | -1 | 8.15 |
| 36 | 1 | -1 | -1 | 1 | -1 | 8.18 |
| 37 | -1 | 1 | 1 | -1 | 1 | 7.18 |
| 38 | 1 | 1 | 1 | 1 | -1 | 7.56 |
| 39 | -1 | -1 | 1 | 1 | 1 | 7.32 |
| 40 | -1 | -1 | 1 | 1 | 1 | 7.44 |
| 41 | 1 | 1 | 1 | 1 | -1 | 7.69 |
| 42 | -1 | -1 | 1 | 1 | 1 | 7.44 |
| 43 | 1 | -1 | 1 | -1 | 1 | 7.69 |
| 44 | 1 | 1 | -1 | -1 | 1 | 7.75 |
| 45 | 1 | -1 | 1 | -1 | -1 | 8.09 |
| 46 | 1 | 1 | 1 | 1 | 1 | 7.59 |
| 47 | -1 | -1 | -1 | -1 | -1 | 7.78 |
| 48 | -1 | -1 | -1 | -1 | 1 | 7.12 |

1. Write out the alias structure for this design. What is the resolution of this design?
2. Analyze the data. What factors influence the mean free height?
3. Calculate the range and standard deviation of the free height for each run. Is there any indication that any of these factors affects variability in the free height?
4. Analyze the residuals from this experiment, and comment on your findings.
5. Is this the best possible design for five factors in 16 runs? Specifically, can you find a fractional design for five factors in 16 runs with a higher resolution than this one?

8.11:

An article in *Industrial and Engineering Chemistry* ("More on Planning Experiments to Increase Research Efficiency," 1970, pp. 60-65) Uses a 25-2 design to investigate the effect of A = condensation temperature, B = amount of material 1, C = solvent volume , D = condesation time, and E = amount of material 2 on yield. The results obtained are as follows:

e = 23.2, ad = 16.9, cd = 23.8, bde = 16.8, ab = 15.5, bc = 16.2 ace = 23.4, abcde = 18.1

1. Verify that the design generators used were I = ACE and I = BDE
2. Write down the complete defining relation and the aliases for this design.
3. Estimate that main effects.
4. Preapare an analysis of variance table. Verify that the AB and AD interactions are available to use as error.
5. Plot the residuals versus the fitted values. Also construct a normal probability plot of the residuals. Comment on the results.

Table 2: Industrial and Engineering Chemistry data

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Condensation | Material 1 | Solvent | Time | Material 2 | Yield |
| 1 | -1 | -1 | -1 | -1 | 1 | 23.2 |
| 2 | 1 | -1 | -1 | 1 | -1 | 16.9 |
| 3 | -1 | 1 | -1 | 1 | 1 | 16.8 |
| 4 | 1 | 1 | -1 | -1 | -1 | 15.5 |
| 5 | -1 | -1 | 1 | 1 | -1 | 23.8 |
| 6 | 1 | -1 | 1 | -1 | 1 | 23.4 |
| 7 | -1 | 1 | 1 | -1 | -1 | 16.2 |
| 8 | 1 | 1 | 1 | 1 | 1 | 18.1 |

8.12:

Consider the leaf spring experiment in Problem 8.7. Suppose that factor E (quench oil temperature) is very difficult to control during manufacturing. Where would you set factors A, B, C, and D to reduce variability in the free height as much as possible regardless of the quench oil temperature used?

8.13:

Construct a 27-2 design by choosing two four-factor interaction as the independent generators. Write down the complete alias structure for this design. Outline the analysis of variance table. What is the resolution of this design?

8.17: Project the design in Example 8.1 into two replicates of a 22 design in the factors A and B. Analyze the data and draw conclusions.