**Modern College of Arts, Science and Commerce, Pune-05**

**Department of Statistics,**

**M.Sc. II (Statistics) Semester IV**

**Date: / /2020 Submission Date: / / 2021**

**Practical No. 2**

**Title: Two way ANOVA without/ with interaction**

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Q1) An experiment was conducted to study the effect of four chemical agents on the strength of a particular type of cloth. A randomized complete block design was applied by considering five bolts of cloth as blocks and four chemical agents as treatments. The resulting tensile strength were recorded as shown in the following table:

**Bolt**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Chemical | 1 | 2 | 3 | 4 | 5 |
| 1 | 91 | 95 | 95 | 93 | 89 |
| 2 | 88 | 93 | 98 | 95 | 88 |
| 3 | 87 | 92 | 95 | 93 | 90 |
| 4 | 88 | 91 | 94 | 93 | 87 |

Analyze the data of this experiment. (Use α= 0.05) and draw appropriate conclusions.

**Required Formulae to Analyse this Example:**

**, where G=**

**RSS=**

**TSS= RSS – CF**

**SSE= TSS---**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Source of Variation** | **Degrees of freedom** | **SS** | **Mss** | **F ratio** | **F critical** |
| **Treatment** | **3** | **12.95** | **4.31** | 2.376147 | 3.490295 |
| **Block** | **4** | 157 | **39.25** | **21.6055** | **3.259167** |
| **Error** | **12** | |  | | --- | | 21.8 | | **1.81667** |  |  |
| **Total** | **19** | |  | | --- | | 191.75 | |  |  |  |

**Ho: All treatment means effects are same**

**H1: Treatment means differ significantly.**

**From above table,**

**F ratio < F critical, accept Ho, implies all treatment mean effects are same.**

**Ho: Block effects are same**

**H1: Block effect differ significantly.**

**From above table,**

**F ratio > F critical, reject Ho, implies block effect differ significantly.**

**2**) An experiment was made to study effectiveness in retarding bacteria growth in 5 gallon milk contains. A randomized block design was used by considering three different washing solutions, four days as treatments and blocks respectively. The data is as shown in following table

**Days**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Solutions | 1 | 2 | 3 | 4 |
| 1 | 25 | 24 | 21 | 42 |
| 2 | 36 | 44 | 37 | 64 |
| 3 | 33 | 42 | 38 | 59 |

Analyze the data. (Use α= 0.05). Interpret your results.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Anova: Two-Factor Without Replication | | | |  |
|  |  |  |  |  |
| *SUMMARY* | *Count* | *Sum* | *Average* | *Variance* |
| Row 1 | 4 | 112 | 28 | 90 |
| Row 2 | 4 | 181 | 45.25 | 168.9166667 |
| Row 3 | 4 | 172 | 43 | 127.3333333 |
|  |  |  |  |  |
| Column 1 | 3 | 94 | 31.33333 | 32.33333333 |
| Column 2 | 3 | 110 | 36.66667 | 121.3333333 |
| Column 3 | 3 | 96 | 32 | 91 |
| Column 4 | 3 | 165 | 55 | 133 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| ANOVA |  |  |  |  |  |  |  |
| ***Source of Variation*** | ***SS*** | ***df*** | ***MS*** | ***F*** | ***P-value*** | ***F crit*** | ***Decision*** |
| Rows | 703.5 | 2 | 351.75 | 40.7170418 | 0.000323155 | 5.14325285 | Reject Ho |
| Columns | 1106.917 | 3 | 368.9722 | 42.71061093 | 0.000192483 | 4.757062663 | Reject Ho |
| Error | 51.83333 | 6 | 8.638889 |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Total | 1862.25 | 11 |  |  |  |  |  |

**Ho: All treatment means effects are same**

**H1: Treatment means differ significantly.**

**From above table,**

**F ratio > F critical, reject Ho, implies all treatment mean effects differ significantly.**

**Ho: Block effects are same**

**H1: Block effect differ significantly.**

**From above table,**

**F ratio > F critical, reject Ho, implies block effect differ significantly.**

1. The yield of a chemical process was studied. The two most important variables are thought to be the pressure and the temperature. Three different temperatures namely1500c, 1600c,and 1700cand three different pressure (in P sig) namely 200,215 and 230 were used. Two observations were taken from each combination of pressure and temperature as shown in following table.

Pressure (P sig)

|  |  |  |  |
| --- | --- | --- | --- |
| Temp (0C) | 200 | 215 | 230 |
| 150 | 80.4 | 80.7 | 80.2 |
|  | 80.4 | 80.7 | 80.2 |
| 160 | 80.1 | 80.5 | 79.9 |
|  | 80.3 | 80.6 | 80.1 |
| 170 | 80.5 | 80.8 | 80.4 |
|  | 80.7 | 80.9 | 80.1 |

* 1. Analyze the data and draw conclusions. Useα= 0.05.
  2. Under what conditions would you operate this process?

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ANOVA |  |  |  |  |  |  |
| Source of Variation | SS | df | MS | F | P-value | F crit |
| Sample | 0.303333 | 2 | 0.151667 | 11.86957 | 0.002994 | 4.256495 |
| Columns | 0.91 | 2 | 0.455 | 35.6087 | 5.31E-05 | 4.256495 |
| Interaction | 0.016667 | 4 | 0.004167 | 0.326087 | 0.853677 | 3.633089 |
|  |  |  |  |  |  |  |
| Total | 1.345 | 17 |  |  |  |  |

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**Ho: Block effects are same**

**H1: Block effect differ significantly.**

**From above table,**

**F ratio >F critical, reject Ho, implies block effect differ significantly.**

**Ho: Interaction effects are same**

**H1: Interaction effect differ significantly.**

**From above table,**

**F ratio < F critical, reject Ho, implies block effect do not differ significantly.**

1. Following data represents the measurements of the surface finish of metal part which was thought to be influenced by the feed rate and the depth of cut.

**Depth of cut (in)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Feed rate ( in min). | 0.15 | 0.18 | 0.20 | 0.25 |
| 0.20 | 84 | 89 | 92 | 109 |
|  | 74 | 78 | 98 | 114 |
|  | 70 | 83 | 102 | 106 |
| 0.25 | 102 | 108 | 109 | 114 |
|  | 96 | 114 | 118 | 120 |
|  | 98 | 98 | 105 | 109 |
| 0.30 | 109 | 114 | 118 | 124 |
|  | 108 | 109 | 120 | 121 |
|  | 112 | 105 | 109 | 117 |

1. Analyze the data & draw conclusions. Use α= 0.01.
2. Prepare appropriate residual plots and comment on the model's adequacy.
3. Obtain point estimates of the mean surface finish at each feed rate.
4. Compute a 95 % confidence interval estimate of the mean difference in response for feed rates of 0.20 and 0.25 in/ mm.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Anova: Two-Factor With Replication |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **SUMMARY** | 0.15 | 0.18 | 0.2 | 0.25 | Total |  |
| *0.2* |  |  |  |  |  |  |
| **Count** | 3 | 3 | 3 | 3 | 12 |  |
| **Sum** | 228 | 250 | 292 | 329 | 1099 |  |
| **Average** | 76 | 83.33333 | 97.33333 | 109.6667 | 91.58333 |  |
| **Variance** | 52 | 30.33333 | 25.33333 | 16.33333 | 205.5379 |  |
|  |  |  |  |  |  |  |
| ***0.25*** |  |  |  |  |  |  |
| **Count** | 3 | 3 | 3 | 3 | 12 |  |
| **Sum** | 296 | 320 | 332 | 343 | 1291 |  |
| **Average** | 98.66667 | 106.6667 | 110.6667 | 114.3333 | 107.5833 |  |
| **Variance** | 9.333333 | 65.33333 | 44.33333 | 30.33333 | 64.08333 |  |
|  |  |  |  |  |  |  |
| ***0.3*** |  |  |  |  |  |  |
| **Count** | 3 | 3 | 3 | 3 | 12 |  |
| **Sum** | 329 | 328 | 347 | 362 | 1366 |  |
| **Average** | 109.6667 | 109.3333 | 115.6667 | 120.6667 | 113.8333 |  |
| **Variance** | 4.333333 | 20.33333 | 34.33333 | 12.33333 | 36.87879 |  |
|  |  |  |  |  |  |  |
| ***Total*** |  |  |  |  |  |  |
| **Count** | 9 | 9 | 9 | 9 |  |  |
| **Sum** | 853 | 898 | 971 | 1034 |  |  |
| **Average** | 94.77778 | 99.77778 | 107.8889 | 114.8889 |  |  |
| **Variance** | 237.4444 | 182.4444 | 93.36111 | 37.61111 |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **ANOVA** |  |  |  |  |  |  |
| ***Source of Variation*** | ***SS*** | ***df*** | ***MS*** | ***F*** | ***P-value*** | ***F crit*** |
| **Sample** | 3160.5 | 2 | 1580.25 | 55.01838 | 1.09E-09 | 3.402826 |
| **Columns** | 2125.111 | 3 | 708.3704 | 24.6628 | 1.65E-07 | 3.008787 |
| **Interaction** | 557.0556 | 6 | 92.84259 | 3.232431 | 0.017973 | 2.508189 |
| **Within** | 689.3333 | 24 | 28.72222 |  |  |  |
|  |  |  |  |  |  |  |
| **Total** | 6532 | 35 |  |  |  |  |

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**Ho: Block effects are same**

**H1: Block effect differ significantly.**

**From above table,**

**F ratio > F critical, reject Ho, implies block effect differ significantly.**

**Ho: Interaction effects are same**

**H1: Interaction effect differ significantly.**

**From above table,**

**F ratio > F critical, reject Ho, implies interaction effect differ significantly.**

5)

Suppose experimenter planting corn. The type of seed and type of fertilizer are the two factors The data that actually appears in the table are samples. In this case, 2 samples from each treatment group were taken.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Fert I | Fert II | Fert III | Fert IV | Fert V |
| Seed A-402 | 106, 110 | 95, 100 | 94, 107 | 103, 104 | 100, 102 |
| Seed B-894 | 110, 112 | 98, 99 | 100, 101 | 108, 112 | 105, 107 |
| Seed C-952 | 94, 97 | 86, 87 | 98, 99 | 99, 101 | 94, 98 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Anova: Two-Factor With Replication | | | |  |  |  |
|  |  |  |  |  |  |  |
| **SUMMARY** | Fert I | Fert II | Fert III | Fert IV | Fert V | Total |
| ***Seed A-402*** |  |  |  |  |  |  |
| **Count** | 2 | 2 | 2 | 2 | 2 | 10 |
| **Sum** | 216 | 195 | 201 | 207 | 202 | 1021 |
| **Average** | 108 | 97.5 | 100.5 | 103.5 | 101 | 102.1 |
| **Variance** | 8 | 12.5 | 84.5 | 0.5 | 2 | 25.65556 |
|  |  |  |  |  |  |  |
| ***Seed B-894*** |  |  |  |  |  |  |
| **Count** | 2 | 2 | 2 | 2 | 2 | 10 |
| **Sum** | 222 | 197 | 201 | 220 | 212 | 1052 |
| **Average** | 111 | 98.5 | 100.5 | 110 | 106 | 105.2 |
| **Variance** | 2 | 0.5 | 0.5 | 8 | 2 | 29.06667 |
|  |  |  |  |  |  |  |
| ***Seed C-952*** |  |  |  |  |  |  |
| **Count** | 2 | 2 | 2 | 2 | 2 | 10 |
| **Sum** | 191 | 173 | 197 | 200 | 192 | 953 |
| **Average** | 95.5 | 86.5 | 98.5 | 100 | 96 | 95.3 |
| **Variance** | 4.5 | 0.5 | 0.5 | 2 | 8 | 26.23333 |
|  |  |  |  |  |  |  |
| ***Total*** |  |  |  |  |  |  |
| **Count** | 6 | 6 | 6 | 6 | 6 |  |
| **Sum** | 629 | 565 | 599 | 627 | 606 |  |
| **Average** | 104.8333 | 94.16667 | 99.83333 | 104.5 | 101 |  |
| **Variance** | 56.96667 | 38.16667 | 18.16667 | 22.7 | 22.4 |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **ANOVA** |  |  |  |  |  |  |
| ***Source of Variation*** | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Sample | 512.8667 | 2 | 256.4333 | 28.28309 | 8.14E-06 | 3.68232 |
| Columns | 449.4667 | 4 | 112.3667 | 12.39338 | 0.000119 | 3.055568 |
| Interaction | 143.1333 | 8 | 17.89167 | 1.973346 | 0.12209 | 2.640797 |
| Within | 136 | 15 | 9.066667 |  |  |  |
|  |  |  |  |  |  |  |
| Total | 1241.467 | 29 |  |  |  |  |

**Ho: All treatment means effects are same**

**H1: Treatment means differ significantly.**

**From above table,**

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**Ho: Block effects are same**

**H1: Block effect differ significantly.**

**From above table,**

**F ratio > F critical, reject Ho, implies block effect differ significantly.**

**Ho: Interaction effects are same**

**H1: Interaction effect differ significantly.**

**From above table,**

**F ratio > F critical,**

**Reject Ho, implies interaction effect differ significantly.**