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# APPENDIX

## The Calculation of $2^5$ Factorial Design

Table A-1: The $2^5$ factorial design of tensile modulus.

| Run Number | Factorial Code | Factor A | B | C | D | E | Modulus (Mpa) | Yates' Algorithm (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 454.90 | 1020.7 | 2174.6 | 4658.5 | 9992.2 | 20340 |  |  |
| 2 | a | + | - | - | - | - | 565.75 | 1153.9 | 2483.9 | 5333.8 | 10347 | 1288.6 | A | 80.54 |
| 3 | b | - | + | - | - | - | 569.92 | 1137.3 | 2514.1 | 4932.9 | 684.0 | 1290.2 | B | 80.64 |
| 4 | ab | + | + | - | - | - | 584.02 | 1346.6 | 2819.7 | 5414.5 | 604.7 | -176.8 | AB | -11.05 |
| 5 | c | - | - | + | - | - | 525.96 | 1155.1 | 2345.8 | 310.9 | 827.9 | 1051.6 | C | 65.73 |
| 6 | ac | + | - | + | - | - | 611.34 | 1359.0 | 2587.0 | 373.0 | 462.3 | -62.8 | AC | -3.92 |
| 7 | bc | - | + | + | - | - | 623.00 | 1269.1 | 2609.5 | 258.1 | -85.7 | 155.1 | BC | 9.69 |
| 8 | abc | + | + | + | - | - | 723.58 | 1550.5 | 2805.0 | 346.5 | -91.1 | -112.9 | ABC | -7.06 |
| 9 | d | - | - | - | + | - | 530.08 | 1119.5 | 125.0 | 342.6 | 614.9 | 1156.9 | D | 72.31 |
| 10 | ad | + | - | - | + | - | 625.00 | 1226.3 | 186.0 | 485.3 | 436.7 | 150.5 | AD | 9.41 |
| 11 | bd | - | + | - | + | - | 618.00 | 1244.5 | 217.9 | 204.8 | -1.8 | 195.5 | BD | 12.22 |
| 12 | abd | + | + | - | + | - | 741.00 | 1342.5 | 155.1 | 257.5 | -61.0 | 79.5 | ABD | 4.97 |
| 13 | cd | - | - | + | + | - | 587.74 | 1243.0 | 147.3 | -81.6 | 153.5 | -49.4 | CD | -3.09 |
| 14 | acd | + | - | + | + | - | 681.40 | 1366.5 | 110.8 | -4.1 | 1.6 | -111.9 | ACD | -6.99 |
| 15 | bcd | - | + | + | + | - | 744.54 | 1335.5 | 185.5 | -46.6 | 51.7 | 20.8 | BCD | 1.30 |
| 16 | abcd | + | + | + | + | - | 806.00 | 1469.5 | 161.0 | -44.5 | -164.6 | -206.6 | ABCD | -12.91 |
| 17 | e | - | - | - | - | + | 525.25 | 110.9 | 133.3 | 309.3 | 675.3 | 355.1 | E | 22.19 |
| 18 | ae | + | - | - | - | + | 594.26 | 14.1 | 209.3 | 305.6 | 481.6 | -79.3 | AE | -4.96 |
| 19 | be | - | + | - | - | + | 574.01 | 85.4 | 203.9 | 241.2 | 62.1 | -365.6 | BE | -22.85 |
| 20 | abe | + | + | - | - | + | 652.30 | 100.6 | 281.4 | 195.5 | 88.4 | -5.4 | ABE | -0.34 |
| 21 | ce | - | - | + | - | + | 580.60 | 94.9 | 106.8 | 61.0 | 142.8 | -178.2 | CE | -11.13 |
| 22 | ace | + | - | + | - | + | 663.93 | 123.0 | 98.0 | -62.8 | 52.8 | -59.2 | ACE | -3.70 |
| 23 | bce | - | + | + | - | + | 657.50 | 93.7 | 123.5 | -36.5 | 77.4 | -151.8 | BCE | -9.49 |
| 24 | abce | + | + | + | - | + | 685.00 | 61.5 | 134.0 | -24.5 | 2.0 | -216.3 | ABCE | -13.52 |
| 25 | de | - | - | - | + | + | 581.97 | 69.0 | -96.8 | 76.0 | -3.7 | -193.7 | DE | -12.10 |
| 26 | ade | + | - | - | + | + | 661.00 | 78.3 | 15.2 | 77.5 | -45.7 | 26.3 | ADE | 1.64 |
| 27 | bde | - | + | - | + | + | 630.00 | 83.3 | 28.1 | -8.8 | -123.8 | -90.0 | BDE | -5.62 |
| 28 | abde | + | + | - | + | + | 736.50 | 27.5 | -32.2 | 10.5 | 11.9 | -75.4 | ABDE | -4.71 |
| 29 | cde | - | - | + | + | + | 609.50 | 79.0 | 9.3 | 112.0 | 1.5 | -42.0 | CDE | -2.62 |
| 30 | acde | + | - | + | + | + | 726.00 | 106.5 | -55.8 | -60.3 | 19.3 | 135.8 | ACDE | 8.48 |
| 31 | bcde | - | + | + | + | + | 712.50 | 116.5 | 27.5 | -65.1 | -172.2 | 17.8 | BCDE | 1.11 |
| 32 | abcde | + | + | + | + | + | 757.00 | 44.5 | -72.0 | -99.5 | -34.4 | 137.9 | ABCDE | 8.62 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | B | 80.64 | 0.9839 |
| 30 | A | 80.54 | 0.9516 |
| 29 | D | 72.31 | 0.9194 |
| 28 | C | 65.73 | 0.8871 |
| 27 | E | 22.19 | 0.8548 |
| 26 | BD | 12.22 | 0.8226 |
| 25 | BC | 9.69 | 0.7903 |
| 24 | AD | 9.41 | 0.7581 |
| 23 | ABCDE | 8.62 | 0.7258 |
| 22 | ACDE | 8.48 | 0.6935 |
| 21 | ABD | 4.97 | 0.6613 |
| 20 | ADE | 1.64 | 0.6290 |
| 19 | BCD | 1.30 | 0.5968 |
| 18 | BCDE | 1.11 | 0.5645 |
| 17 | ABE | -0.34 | 0.5323 |
| 16 | CDE | -2.62 | 0.5000 |
| 15 | CD | -3.09 | 0.4677 |
| 14 | ACE | -3.70 | 0.4355 |
| 13 | AC | -3.92 | 0.4032 |
| 12 | ABDE | -4.71 | 0.3710 |
| 11 | AE | -4.96 | 0.3387 |
| 10 | BDE | -5.62 | 0.3065 |
| 9 | ACD | -6.99 | 0.2742 |
| 8 | ABC | -7.06 | 0.2419 |
| 7 | BCE | -9.49 | 0.2097 |
| 6 | AB | -11.05 | 0.1774 |
| 5 | CE | -11.13 | 0.1452 |
| 4 | DE | -12.10 | 0.1129 |
| 3 | ABCD | -12.91 | 0.0806 |
| 2 | ABCE | -13.52 | 0.0484 |
| 1 | BE | -22.85 | 0.0161 |

Table A-2:  The $2^5$ factorial design of tensile yield stress.

| Run Number | Factorial Code | A | B | C | D | E | Yield stress (Mpa) | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 8.24 | 19.2 | 41.9 | 84.0 | 176.9 | 354 | | |
| 2 | a | + | - | - | - | - | 10.94 | 22.7 | 42.1 | 92.9 | 177 | 19.3 | A | 1.21 |
| 3 | b | - | + | - | - | - | 11.01 | 19.1 | 43.5 | 86.7 | 9.3 | 22.1 | B | 1.38 |
| 4 | ab | + | + | - | - | - | 11.68 | 23.0 | 49.5 | 90.3 | 10.0 | -6.0 | AB | -0.38 |
| 5 | c | - | - | + | - | - | 9.29 | 20.0 | 42.8 | 4.7 | 15.9 | 9.4 | C | 0.59 |
| 6 | ac | + | - | + | - | - | 9.84 | 23.5 | 43.9 | 4.6 | 6.1 | -1.8 | AC | -0.11 |
| 7 | bc | - | + | + | - | - | 11.07 | 22.2 | 44.1 | 3.8 | 0.1 | 0.1 | BC | 0.01 |
| 8 | abc | + | + | + | - | - | 11.89 | 27.3 | 46.2 | 6.2 | 0.3 | 0.3 | ABC | 0.02 |
| 9 | d | - | - | - | + | - | 9.97 | 19.9 | 3.4 | 7.3 | 6.2 | 12.6 | D | 0.79 |
| 10 | ad | + | - | - | + | - | 10.00 | 22.9 | 1.4 | 8.6 | 3.2 | 2.2 | AD | 0.14 |
| 11 | bd | - | + | - | + | - | 10.72 | 22.2 | 2.1 | 2.5 | -1.6 | 2.3 | BD | 0.15 |
| 12 | abd | + | + | - | + | - | 12.77 | 21.7 | 2.5 | 3.6 | -0.2 | 5.6 | ABD | 0.35 |
| 13 | cd | - | - | + | + | - | 10.45 | 21.6 | 2.9 | -1.8 | 1.9 | 6.8 | CD | 0.43 |
| 14 | acd | + | - | + | + | - | 11.75 | 22.5 | 0.9 | 1.9 | -1.8 | 6.3 | ACD | 0.39 |
| 15 | bcd | - | + | + | + | - | 13.05 | 21.8 | 2.2 | -4.0 | 0.2 | 6.4 | BCD | 0.40 |
| 16 | abcd | + | + | + | + | - | 14.23 | 24.4 | 4.0 | -2.1 | 0.1 | -7.2 | ABCD | -0.45 |
| 17 | e | - | - | - | - | + | 8.53 | 2.7 | 3.5 | 0.2 | 9.0 | 0.1 | E | 0.01 |
| 18 | ae | + | - | - | - | + | 11.36 | 0.7 | 3.8 | 6.0 | 3.6 | 0.7 | AE | 0.05 |
| 19 | be | - | + | - | - | + | 11.40 | 0.6 | 3.5 | 1.1 | -0.2 | -9.8 | BE | -0.61 |
| 20 | abe | + | + | - | - | + | 11.50 | 0.8 | 5.1 | 2.1 | 2.4 | -6.3 | ABE | -0.40 |
| 21 | ce | - | - | + | - | + | 10.54 | 0.0 | 3.0 | -2.0 | 1.3 | -3.0 | CE | -0.19 |
| 22 | ace | + | - | + | - | + | 11.64 | 2.1 | -0.5 | 0.4 | 1.1 | 1.4 | ACE | 0.09 |
| 23 | bce | - | + | + | - | + | 10.96 | 1.3 | 1.0 | -2.0 | 3.7 | -3.7 | BCE | -0.23 |
| 24 | abce | + | + | + | - | + | 10.75 | 1.2 | 2.7 | 1.8 | 1.9 | -0.1 | ABCE | 0.00 |
| 25 | de | - | - | - | + | + | 10.14 | 2.8 | -2.0 | 0.3 | -5.3 | -5.3 | DE | -0.33 |
| 26 | ade | + | - | - | + | + | 11.44 | 0.1 | 0.3 | 1.6 | 2.6 | 2.6 | ADE | 0.16 |
| 27 | bde | - | + | - | + | + | 10.82 | 1.1 | 2.0 | -3.5 | -0.2 | -0.2 | BDE | -0.01 |
| 28 | abde | + | + | - | + | + | 11.71 | -0.2 | -0.1 | 1.7 | -1.8 | -1.8 | ABDE | -0.11 |
| 29 | cde | - | - | + | + | + | 9.45 | 1.3 | -2.7 | 2.3 | 3.9 | -4.8 | CDE | -0.30 |
| 30 | acde | + | - | + | + | + | 12.33 | 0.9 | -1.3 | -2.1 | 5.2 | 1.5 | ACDE | 0.09 |
| 31 | bcde | - | + | + | + | + | 11.64 | 2.9 | -0.4 | 1.4 | -4.4 | 3.9 | BCDE | 0.25 |
| 32 | abcde | + | + | + | + | + | 12.79 | 1.2 | -1.7 | -1.3 | -2.7 | 1.7 | ABCDE | 0.11 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | B | 1.38 | 0.9839 |
| 30 | A | 1.21 | 0.9516 |
| 29 | D | 0.79 | 0.9194 |
| 28 | C | 0.59 | 0.8871 |
| 27 | CD | 0.43 | 0.8548 |
| 26 | BCD | 0.40 | 0.8226 |
| 25 | ACD | 0.39 | 0.7903 |
| 24 | ABD | 0.35 | 0.7581 |
| 23 | BCDE | 0.25 | 0.7258 |
| 22 | ADE | 0.16 | 0.6935 |
| 21 | BD | 0.15 | 0.6613 |
| 20 | AD | 0.14 | 0.6290 |
| 19 | ABCDE | 0.11 | 0.5968 |
| 18 | ACDE | 0.09 | 0.5645 |
| 17 | ACE | 0.09 | 0.5323 |
| 16 | AE | 0.05 | 0.5000 |
| 15 | ABC | 0.02 | 0.4677 |
| 14 | BC | 0.01 | 0.4355 |
| 13 | E | 0.01 | 0.4032 |
| 12 | ABCE | 0.00 | 0.3710 |
| 11 | BDE | -0.01 | 0.3387 |
| 10 | ABDE | -0.11 | 0.3065 |
| 9 | AC | -0.11 | 0.2742 |
| 8 | CE | -0.19 | 0.2419 |
| 7 | BCE | -0.23 | 0.2097 |
| 6 | CDE | -0.30 | 0.1774 |
| 5 | DE | -0.33 | 0.1452 |
| 4 | AB | -0.38 | 0.1129 |
| 3 | ABE | -0.40 | 0.0806 |
| 2 | ABCD | -0.45 | 0.0484 |
| 1 | BE | -0.61 | 0.0161 |

Table A-3: The $2^5$ factorial design of tensile yield strain.

| Run Number | Factorial Code | A | B | C | D | E | Yield strain (%) | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 2.16 | 3.9 | 7.1 | 13.7 | 26.6 | 52 | - | - |
| 2 | a | + | - | - | - | - | 1.71 | 3.3 | 6.6 | 12.9 | 26 | -1.8 | A | -0.110 |
| 3 | b | - | + | - | - | - | 1.66 | 3.3 | 6.4 | 13.5 | -1.2 | -1.6 | B | -0.102 |
| 4 | ab | + | + | - | - | - | 1.60 | 3.3 | 6.5 | 12.3 | -0.6 | 0.4 | AB | 0.023 |
| 5 | c | - | - | + | - | - | 1.80 | 3.2 | 7.1 | -1.0 | -0.4 | -1.9 | C | -0.118 |
| 6 | ac | + | - | + | - | - | 1.48 | 3.2 | 6.4 | -0.2 | -1.2 | 0.5 | AC | 0.030 |
| 7 | bc | - | + | + | - | - | 1.74 | 3.2 | 6.5 | -0.4 | 0.6 | 0.8 | BC | 0.052 |
| 8 | abc | + | + | + | - | - | 1.53 | 3.3 | 5.8 | -0.2 | -0.2 | -0.8 | ABC | -0.050 |
| 9 | d | - | - | - | + | - | 1.65 | 3.7 | -0.5 | -0.6 | -0.5 | -2.0 | D | -0.124 |
| 10 | ad | + | - | - | + | - | 1.50 | 3.4 | -0.5 | 0.2 | -1.4 | 1.1 | AD | 0.066 |
| 11 | bd | - | + | - | + | - | 1.64 | 3.4 | -0.2 | -0.7 | 0.2 | 1.1 | BD | 0.066 |
| 12 | abd | + | + | - | + | - | 1.60 | 2.9 | 0.0 | -0.5 | 0.3 | -0.5 | ABD | -0.034 |
| 13 | cd | - | - | + | + | - | 1.58 | 3.5 | -0.2 | 0.5 | 0.6 | 0.8 | CD | 0.052 |
| 14 | acd | + | - | + | + | - | 1.60 | 3.0 | -0.2 | 0.1 | 0.2 | 0.6 | ACD | 0.039 |
| 15 | bcd | - | + | + | + | - | 1.64 | 2.9 | -0.3 | 0.0 | -0.4 | 0.1 | BCD | 0.004 |
| 16 | abcd | + | + | + | + | - | 1.66 | 2.9 | 0.1 | -0.2 | -0.4 | -0.1 | ABCD | -0.003 |
| 17 | e | - | - | - | - | + | 1.89 | -0.5 | -0.6 | -0.6 | -0.8 | -0.8 | E | -0.048 |
| 18 | ae | + | - | - | - | + | 1.80 | -0.1 | 0.0 | 0.1 | -1.2 | 0.6 | AE | 0.039 |
| 19 | be | - | + | - | - | + | 1.75 | -0.3 | 0.1 | -0.8 | 0.9 | -0.8 | BE | -0.051 |
| 20 | abe | + | + | - | - | + | 1.69 | -0.2 | 0.1 | -0.6 | 0.2 | -0.9 | ABE | -0.053 |
| 21 | ce | - | - | + | - | + | 1.74 | -0.2 | -0.3 | 0.0 | 0.8 | -0.9 | CE | -0.057 |
| 22 | ace | + | - | + | - | + | 1.67 | 0.0 | -0.5 | 0.2 | 0.2 | 0.1 | ACE | 0.003 |
| 23 | bce | - | + | + | - | + | 1.54 | 0.0 | -0.5 | -0.1 | -0.4 | -0.4 | BCE | -0.027 |
| 24 | abce | + | + | + | - | + | 1.40 | 0.0 | 0.0 | 0.3 | -0.2 | 0.0 | ABCE | -0.002 |
| 25 | de | - | - | - | + | + | 1.81 | 0.0 | 0.4 | 0.6 | -0.4 | -0.4 | DE | -0.023 |
| 26 | ade | + | - | - | + | + | 1.65 | -0.1 | 0.1 | 0.0 | 0.7 | -0.7 | ADE | -0.045 |
| 27 | bde | - | + | - | + | + | 1.55 | -0.1 | 0.1 | -0.2 | 0.2 | -0.6 | BDE | -0.038 |
| 28 | abde | + | + | - | + | + | 1.45 | -0.1 | 0.0 | 0.4 | 0.3 | 0.2 | ABDE | 0.015 |
| 29 | cde | - | - | + | + | + | 1.39 | -0.2 | 0.0 | 0.0 | 0.4 | -0.5 | CDE | -0.032 |
| 30 | acde | + | - | + | + | + | 1.55 | -0.1 | -0.1 | -0.3 | -0.6 | 0.1 | ACDE | 0.008 |
| 31 | bcde | - | + | + | + | + | 1.50 | 0.2 | -0.1 | -0.1 | 0.6 | 1.2 | BCDE | 0.075 |
| 32 | abcde | + | + | + | + | + | 1.40 | -0.1 | -0.3 | -0.1 | 0.2 | -0.4 | ABCDE | -0.025 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | BCDE | 0.075 | 0.9839 |
| 30 | AD | 0.066 | 0.9516 |
| 29 | BD | 0.066 | 0.9194 |
| 28 | BC | 0.052 | 0.8871 |
| 27 | CD | 0.052 | 0.8548 |
| 26 | ACD | 0.039 | 0.8226 |
| 25 | AE | 0.039 | 0.7903 |
| 24 | AC | 0.030 | 0.7581 |
| 23 | AB | 0.023 | 0.7258 |
| 22 | ABDE | 0.015 | 0.6935 |
| 21 | ACDE | 0.008 | 0.6613 |
| 20 | BCD | 0.004 | 0.6290 |
| 19 | ACE | 0.003 | 0.5968 |
| 18 | ABCE | -0.002 | 0.5645 |
| 17 | ABCD | -0.003 | 0.5323 |
| 16 | DE | -0.023 | 0.5000 |
| 15 | ABCDE | -0.025 | 0.4677 |
| 14 | BCE | -0.027 | 0.4355 |
| 13 | CDE | -0.032 | 0.4032 |
| 12 | ABD | -0.034 | 0.3710 |
| 11 | BDE | -0.038 | 0.3387 |
| 10 | ADE | -0.045 | 0.3065 |
| 9 | E | -0.048 | 0.2742 |
| 8 | ABC | -0.050 | 0.2419 |
| 7 | BE | -0.051 | 0.2097 |
| 6 | ABE | -0.053 | 0.1774 |
| 5 | CE | -0.057 | 0.1452 |
| 4 | B | -0.102 | 0.1129 |
| 3 | A | -0.110 | 0.0806 |
| 2 | C | -0.118 | 0.0484 |
| 1 | D | -0.124 | 0.0161 |

Table A-4: The 2⁵ factorial design of hardness test.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect | | Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 679.60 | 1370.2 | 2768.5 | 5542.0 | 11109 | 22379 | | | | 31 | B | 1.118 | 0.9839 |
| 2 | a | + | - | - | - | - | 690.60 | 1398.3 | 2773.5 | 5567.3 | 11270 | 178.50 | A | 1.116 | | 30 | A | 1.116 | 0.9516 |
| 3 | b | - | + | - | - | - | 692.50 | 1372.4 | 2774.4 | 5632.3 | 94.10 | 178.90 | B | 1.118 | | 29 | E | 1.004 | 0.9194 |
| 4 | ab | + | + | - | - | - | 705.80 | 1401.1 | 2792.9 | 5637.7 | 84.40 | 11.30 | AB | 0.071 | | 28 | D | 0.192 | 0.8871 |
| 5 | c | - | - | + | - | - | 682.80 | 1377.3 | 2814.1 | 44.80 | 105.50 | 29.70 | C | 0.186 | | 27 | C | 0.186 | 0.8548 |
| 6 | ac | + | - | + | - | - | 689.60 | 1397.1 | 2818.2 | 49.30 | 73.40 | 1.30 | AC | 0.008 | | 26 | ACD | 0.124 | 0.8226 |
| 7 | bc | - | + | + | - | - | 693.70 | 1382.0 | 2817.8 | 45.50 | 18.30 | 4.10 | BC | 0.026 | | 25 | ABDE | 0.118 | 0.7903 |
| 8 | abc | + | + | + | - | - | 707.40 | 1410.9 | 2819.9 | 38.90 | -7.00 | -1.50 | ABC | -0.009 | | 24 | BCD | 0.117 | 0.7581 |
| 9 | d | - | - | - | + | - | 684.40 | 1394.7 | 24.30 | 56.80 | 23.50 | 30.70 | D | 0.192 | | 23 | ABD | 0.117 | 0.7258 |
| 10 | ad | + | - | - | + | - | 692.90 | 1419.4 | 20.50 | 48.70 | 6.20 | -2.10 | AD | -0.013 | | 22 | ACDE | 0.091 | 0.6935 |
| 11 | bd | - | + | - | + | - | 690.20 | 1400.7 | 25.20 | 41.50 | -4.90 | -17.70 | BD | -0.111 | | 21 | CD | 0.072 | 0.6613 |
| 12 | abd | + | + | - | + | - | 706.90 | 1417.5 | 24.10 | 31.90 | 6.20 | 18.70 | ABD | 0.117 | | 20 | AB | 0.071 | 0.6290 |
| 13 | cd | - | - | + | + | - | 685.20 | 1401.5 | 25.50 | 9.20 | 9.70 | 11.50 | CD | 0.072 | | 19 | ACE | 0.069 | 0.5968 |
| 14 | acd | + | - | + | + | - | 696.80 | 1416.3 | 20.00 | 9.10 | -5.60 | 19.90 | ACD | 0.124 | | 18 | BC | 0.026 | 0.5645 |
| 15 | bcd | - | + | + | + | - | 699.20 | 1401.4 | 13.60 | -12.90 | -2.70 | 18.70 | BCD | 0.117 | | 17 | ABCE | 0.024 | 0.5323 |
| 16 | abcd | + | + | + | + | - | 711.70 | 1418.5 | 25.30 | 5.90 | 1.20 | -22.90 | ABCD | -0.143 | | 16 | BCDE | 0.011 | 0.5000 |
| 17 | e | - | - | - | - | + | 688.60 | 11.00 | 28.10 | 5.00 | 25.30 | 160.70 | E | 1.004 | | 15 | AC | 0.008 | 0.4677 |
| 18 | ae | + | - | - | - | + | 706.10 | 13.30 | 28.70 | 18.50 | 5.40 | -9.70 | AE | -0.061 | | 14 | ABCDE | 0.006 | 0.4355 |
| 19 | be | - | + | - | - | + | 705.70 | 6.80 | 19.80 | 4.10 | 4.50 | -32.10 | BE | -0.201 | | 13 | BDE | -0.009 | 0.4032 |
| 20 | abe | + | + | - | - | + | 713.70 | 13.70 | 28.90 | 2.10 | -6.60 | -25.30 | ABE | -0.158 | | 12 | ABC | -0.009 | 0.3710 |
| 21 | ce | - | - | + | - | + | 694.50 | 8.50 | 24.70 | -3.80 | -8.10 | -17.30 | CE | -0.108 | | 11 | AD | -0.013 | 0.3387 |
| 22 | ace | + | - | + | - | + | 706.20 | 16.70 | 16.80 | -1.10 | -9.60 | 11.10 | ACE | 0.069 | | 10 | AE | -0.061 | 0.3065 |
| 23 | bce | - | + | + | - | + | 704.60 | 11.60 | 14.80 | -5.50 | -0.10 | -15.30 | BCE | -0.096 | | 9 | ADE | -0.069 | 0.2742 |
| 24 | abce | + | + | + | - | + | 712.90 | 12.50 | 17.10 | 11.70 | 18.80 | 3.90 | ABCE | 0.024 | | 8 | BCE | -0.096 | 0.2419 |
| 25 | de | - | - | - | + | + | 698.70 | 17.50 | 2.30 | 0.60 | 13.50 | -19.90 | DE | -0.124 | | 7 | CDE | -0.097 | 0.2097 |
| 26 | ade | + | - | - | + | + | 702.80 | 8.00 | 6.90 | 9.10 | -2.00 | -11.10 | ADE | -0.069 | | 6 | CE | -0.108 | 0.1774 |
| 27 | bde | - | + | - | + | + | 703.40 | 11.70 | 8.20 | -7.90 | 2.70 | -1.50 | BDE | -0.009 | | 5 | BD | -0.111 | 0.1452 |
| 28 | abde | + | + | - | + | + | 712.90 | 8.30 | 0.90 | 2.30 | 17.20 | 18.90 | ABDE | 0.118 | | 4 | DE | -0.124 | 0.1129 |
| 29 | cde | - | - | + | + | + | 694.50 | 4.10 | -9.50 | 4.60 | 8.50 | -15.50 | CDE | -0.097 | | 3 | ABCD | -0.143 | 0.0806 |
| 30 | acde | + | - | + | + | + | 706.90 | 9.50 | -3.40 | -7.30 | 10.20 | 14.50 | ACDE | 0.091 | | 2 | ABE | -0.158 | 0.0484 |
| 31 | bcde | - | + | + | + | + | 702.80 | 12.40 | 5.40 | 6.10 | -11.90 | 1.70 | BCDE | 0.011 | | 1 | BE | -0.201 | 0.0161 |
| 32 | abcde | + | + | + | + | + | 715.70 | 12.90 | 0.50 | -4.90 | -11.00 | 0.90 | ABCDE | 0.006 | | | | | |

## Table A-5: The 2⁵ factorial design of Izod impact test.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 40.51 | 65.64 | 117.49 | 216.91 | 413.35 | 786.68 |  |  |
| 2 | a | + | - | - | - | - | 25.13 | 51.86 | 99.41 | 196.45 | 373.32 | -70.52 | A | -0.441 |
| 3 | b | - | + | - | - | - | 26.68 | 54.23 | 100.09 | 195.15 | -37.58 | -76.28 | B | -0.477 |
| 4 | ab | + | + | - | - | - | 25.18 | 45.18 | 96.36 | 178.18 | -32.95 | -13.63 | AB | -0.085 |
| 5 | c | - | - | + | - | - | 27.75 | 54.64 | 105.15 | -23.38 | -41.12 | -43.97 | C | -0.275 |
| 6 | ac | + | - | + | - | - | 26.47 | 45.44 | 90.00 | -14.20 | -35.16 | 25.07 | AC | 0.157 |
| 7 | bc | - | + | + | - | - | 25.20 | 52.73 | 92.59 | -18.57 | 4.31 | 4.74 | BC | 0.030 |
| 8 | abc | + | + | + | - | - | 19.99 | 43.63 | 85.59 | -14.38 | -17.94 | -8.36 | ABC | -0.052 |
| 9 | d | - | - | - | + | - | 28.06 | 58.59 | -16.88 | -22.82 | -21.81 | -37.43 | D | -0.234 |
| 10 | ad | + | - | - | + | - | 26.59 | 46.55 | -6.49 | -18.30 | -22.16 | 13.36 | AD | 0.084 |
| 11 | bd | - | + | - | + | - | 27.13 | 47.98 | -10.28 | -18.01 | 16.76 | 5.38 | BD | 0.034 |
| 12 | abd | + | + | - | + | - | 18.31 | 42.01 | -3.92 | -17.15 | 8.32 | -11.37 | ABD | -0.071 |
| 13 | cd | - | - | + | + | - | 27.77 | 49.04 | -11.55 | 9.95 | 4.83 | 22.50 | CD | 0.141 |
| 14 | acd | + | - | + | + | - | 24.96 | 43.55 | -7.02 | -5.64 | -0.09 | -4.78 | ACD | -0.030 |
| 15 | bcd | - | + | + | + | - | 22.37 | 48.62 | -9.08 | -11.08 | -8.75 | -16.86 | BCD | -0.105 |
| 16 | abcd | + | + | + | + | - | 21.26 | 36.97 | -5.30 | -6.86 | 0.39 | 35.05 | ABCD | 0.219 |
| 17 | e | - | - | - | - | + | 31.29 | -15.38 | -13.78 | -18.08 | -20.46 | -40.03 | E | -0.250 |
| 18 | ae | + | - | - | - | + | 27.31 | -1.50 | -9.04 | -3.73 | -16.97 | 4.63 | AE | 0.029 |
| 19 | be | - | + | - | - | + | 27.06 | -1.28 | -9.20 | -15.15 | 9.17 | 5.96 | BE | 0.037 |
| 20 | abe | + | + | - | - | + | 19.49 | -5.21 | -9.10 | -7.01 | 4.19 | -22.25 | ABE | -0.139 |
| 21 | ce | - | - | + | - | + | 23.88 | -1.47 | -12.04 | 10.39 | 4.52 | -0.35 | CE | -0.002 |
| 22 | ace | + | - | + | - | + | 24.11 | -8.82 | -5.97 | 6.36 | 0.85 | -8.44 | ACE | -0.053 |
| 23 | bce | - | + | + | - | + | 24.63 | -2.82 | -5.50 | 4.53 | -15.59 | -4.92 | BCE | -0.031 |
| 24 | abce | + | + | + | - | + | 17.38 | -1.10 | -11.65 | 3.79 | 4.21 | 9.15 | ABCE | 0.057 |
| 25 | de | - | - | - | + | + | 25.40 | -3.98 | 13.88 | 4.73 | 14.36 | 3.49 | DE | 0.022 |
| 26 | ade | + | - | - | + | + | 23.65 | -7.57 | -3.93 | 0.10 | 8.14 | -4.98 | ADE | -0.031 |
| 27 | bde | - | + | - | + | + | 25.44 | 0.23 | -7.35 | 6.07 | -4.03 | -3.67 | BDE | -0.023 |
| 28 | abde | + | + | - | + | + | 18.11 | -7.25 | 1.71 | -6.16 | -0.74 | 19.80 | ABDE | 0.124 |
| 29 | cde | - | - | + | + | + | 25.31 | -1.75 | -3.59 | -17.82 | -4.63 | -6.21 | CDE | -0.039 |
| 30 | acde | + | - | + | + | + | 23.31 | -7.33 | -7.48 | 9.06 | -12.23 | 3.29 | ACDE | 0.021 |
| 31 | bcde | - | + | + | + | + | 20.13 | -2.00 | -5.57 | -3.89 | 26.88 | -7.60 | BCDE | -0.047 |
| 32 | abcde | + | + | + | + | + | 16.84 | -3.29 | -1.29 | 4.28 | 8.17 | -18.70 | ABCDE | -0.117 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | ABCD | 0.219 | 0.9839 |
| 30 | AC | 0.157 | 0.9516 |
| 29 | CD | 0.141 | 0.9194 |
| 28 | ABDE | 0.124 | 0.8871 |
| 27 | AD | 0.084 | 0.8548 |
| 26 | ABCE | 0.057 | 0.8226 |
| 25 | BE | 0.037 | 0.7903 |
| 24 | BD | 0.034 | 0.7581 |
| 23 | BC | 0.030 | 0.7258 |
| 22 | AE | 0.029 | 0.6935 |
| 21 | DE | 0.022 | 0.6613 |
| 20 | ACDE | 0.021 | 0.6290 |
| 19 | CE | -0.002 | 0.5968 |
| 18 | BDE | -0.023 | 0.5645 |
| 17 | ACD | -0.030 | 0.5323 |
| 16 | BCE | -0.031 | 0.5000 |
| 15 | ADE | -0.031 | 0.4677 |
| 14 | CDE | -0.039 | 0.4355 |
| 13 | BCDE | -0.047 | 0.4032 |
| 12 | ABC | -0.052 | 0.3710 |
| 11 | ACE | -0.053 | 0.3387 |
| 10 | ABD | -0.071 | 0.3065 |
| 9 | AB | -0.085 | 0.2742 |
| 8 | BCD | -0.105 | 0.2419 |
| 7 | ABCDE | -0.117 | 0.2097 |
| 6 | ABE | -0.139 | 0.1774 |
| 5 | D | -0.234 | 0.1452 |
| 4 | E | -0.250 | 0.1129 |
| 3 | C | -0.275 | 0.0806 |
| 2 | A | -0.441 | 0.0484 |
| 1 | B | -0.477 | 0.0161 |

Table A-6: The 2⁵ factorial design of falling weight absorption impact energy.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 158.47 | 180.88 | 220.04 | 278.77 | 365.77 | 632.98 | | |
| 2 | a | + | - | - | - | - | 22.41 | 39.16 | 58.73 | 87.00 | 267.21 | -211.16 | A | -3.299 |
| 3 | b | - | + | - | - | - | 22.68 | 32.24 | 46.20 | 171.28 | -151.45 | -210.30 | B | -3.286 |
| 4 | ab | + | + | - | - | - | 16.48 | 26.49 | 40.80 | 95.93 | -59.71 | 173.36 | AB | 2.709 |
| 5 | c | - | - | + | - | - | 18.77 | 24.94 | 124.68 | -146.37 | -158.31 | -245.52 | C | -3.836 |
| 6 | ac | + | - | + | - | - | 13.47 | 21.26 | 46.60 | -5.08 | -51.99 | 187.50 | AC | 2.930 |
| 7 | bc | - | + | + | - | - | 12.65 | 23.98 | 48.33 | -55.58 | 131.31 | 179.40 | BC | 2.803 |
| 8 | abc | + | + | + | - | - | 13.84 | 16.82 | 47.60 | -4.13 | 42.05 | -176.82 | ABC | -2.763 |
| 9 | d | - | - | - | + | - | 13.39 | 87.65 | -142.26 | -147.47 | -166.71 | -267.12 | D | -4.174 |
| 10 | ad | + | - | - | + | - | 11.55 | 37.03 | -4.11 | -10.84 | -78.81 | 192.74 | AD | 3.012 |
| 11 | bd | - | + | - | + | - | 12.15 | 24.50 | -4.88 | -53.02 | 142.83 | 190.68 | BD | 2.979 |
| 12 | abd | + | + | - | + | - | 9.11 | 22.10 | -0.20 | 1.03 | 44.67 | -190.54 | ABD | -2.977 |
| 13 | cd | - | - | + | + | - | 11.08 | 23.58 | -54.52 | 136.35 | 132.49 | 233.26 | CD | 3.645 |
| 14 | acd | + | - | + | + | - | 12.90 | 24.75 | -1.06 | -5.04 | 46.91 | -195.72 | ACD | -3.058 |
| 15 | bcd | - | + | + | + | - | 9.42 | 23.87 | 2.33 | 45.60 | -126.01 | -188.98 | BCD | -2.953 |
| 16 | abcd | + | + | + | + | - | 7.40 | 23.73 | -6.46 | -3.55 | -50.81 | 170.48 | ABCD | 2.664 |
| 17 | e | - | - | - | - | + | 69.44 | -136.06 | -141.72 | -161.31 | -191.77 | -98.56 | E | -1.540 |
| 18 | ae | + | - | - | - | + | 18.21 | -6.20 | -5.75 | -5.40 | -75.35 | 91.74 | AE | 1.433 |
| 19 | be | - | + | - | - | + | 20.16 | -5.30 | -3.68 | -78.08 | 141.29 | 106.32 | BE | 1.661 |
| 20 | abe | + | + | - | - | + | 16.87 | 1.19 | -7.16 | -0.73 | 51.45 | -89.26 | ABE | -1.395 |
| 21 | ce | - | - | + | - | + | 11.93 | -1.84 | -50.62 | 138.15 | 136.63 | 87.90 | CE | 1.373 |
| 22 | ace | + | - | + | - | + | 12.57 | -3.04 | -2.40 | 4.68 | 54.05 | -98.16 | ACE | -1.534 |
| 23 | bce | - | + | + | - | + | 11.90 | 1.82 | 1.17 | 53.46 | -141.39 | -85.58 | BCE | -1.337 |
| 24 | abce | + | + | + | - | + | 10.20 | -2.02 | -0.14 | -8.79 | -49.15 | 75.20 | ABCE | 1.175 |
| 25 | de | - | - | - | + | + | 10.83 | -51.23 | 129.86 | 135.97 | 155.91 | 116.42 | DE | 1.819 |
| 26 | ade | + | - | - | + | + | 12.75 | -3.29 | 6.49 | -3.48 | 77.35 | -89.84 | ADE | -1.404 |
| 27 | bde | - | + | - | + | + | 12.17 | 0.64 | -1.20 | 48.22 | -133.47 | -82.58 | BDE | -1.290 |
| 28 | abde | + | + | - | + | + | 12.58 | -1.70 | -3.84 | -1.31 | -62.25 | 92.24 | ABDE | 1.441 |
| 29 | cde | - | - | + | + | + | 13.04 | 1.92 | 47.94 | -123.37 | -139.45 | -78.56 | CDE | -1.228 |
| 30 | acde | + | - | + | + | + | 10.83 | 0.41 | -2.34 | -2.64 | -49.53 | 71.22 | ACDE | 1.113 |
| 31 | bcde | - | + | + | + | + | 13.99 | -2.21 | -1.51 | -50.28 | 120.73 | 89.92 | BCDE | 1.405 |
| 32 | abcde | + | + | + | + | + | 9.74 | -4.25 | -2.04 | -0.53 | 49.75 | -70.98 | ABCDE | -1.109 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | CD | 3.645 | 0.9839 |
| 30 | AD | 3.012 | 0.9516 |
| 29 | BD | 2.979 | 0.9194 |
| 28 | AC | 2.930 | 0.8871 |
| 27 | BC | 2.803 | 0.8548 |
| 26 | AB | 2.709 | 0.8226 |
| 25 | ABCD | 2.664 | 0.7903 |
| 24 | DE | 1.819 | 0.7581 |
| 23 | BE | 1.661 | 0.7258 |
| 22 | ABDE | 1.441 | 0.6935 |
| 21 | AE | 1.433 | 0.6613 |
| 20 | BCDE | 1.405 | 0.6290 |
| 19 | CE | 1.373 | 0.5968 |
| 18 | ABCE | 1.175 | 0.5645 |
| 17 | ACDE | 1.113 | 0.5323 |
| 16 | ABCDE | -1.109 | 0.5000 |
| 15 | CDE | -1.228 | 0.4677 |
| 14 | BDE | -1.290 | 0.4355 |
| 13 | BCE | -1.337 | 0.4032 |
| 12 | ABE | -1.395 | 0.3710 |
| 11 | ADE | -1.404 | 0.3387 |
| 10 | ACE | -1.534 | 0.3065 |
| 9 | E | -1.540 | 0.2742 |
| 8 | ABC | -2.763 | 0.2419 |
| 7 | BCD | -2.953 | 0.2097 |
| 6 | ABD | -2.977 | 0.1774 |
| 5 | ACD | -3.058 | 0.1452 |
| 4 | B | -3.286 | 0.1129 |
| 3 | A | -3.299 | 0.0806 |
| 2 | C | -3.836 | 0.0484 |
| 1 | D | -4.174 | 0.0161 |

Table A-7: The $2^5$ factorial design of falling weight impact deformation.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 116.08 | 166.12 | 280.92 | 527.01 | 932.78 | 1832.06 | | |
| 2 | a | + | - | - | - | - | 50.04 | 114.81 | 246.09 | 405.77 | 899.28 | -144.56 | A | -2.259 |
| 3 | b | - | + | - | - | - | 58.04 | 131.02 | 208.79 | 432.35 | -82.38 | -140.50 | B | -2.195 |
| 4 | ab | + | + | - | - | - | 56.77 | 115.07 | 196.98 | 466.94 | -62.19 | 138.39 | AB | 2.162 |
| 5 | c | - | - | + | - | - | 74.00 | 111.89 | 206.16 | -73.36 | -106.00 | -42.71 | C | -0.667 |
| 6 | ac | + | - | + | - | - | 57.02 | 96.90 | 226.19 | -9.02 | -34.50 | 17.91 | AC | 0.280 |
| 7 | bc | - | + | + | - | - | 52.07 | 110.36 | 241.51 | -31.28 | 91.78 | 20.96 | BC | 0.327 |
| 8 | abc | + | + | + | - | - | 63.00 | 86.61 | 225.43 | -30.90 | 46.61 | -90.46 | ABC | -1.413 |
| 9 | d | - | - | - | + | - | 58.42 | 107.61 | -67.31 | -67.26 | -46.65 | -86.66 | D | -1.354 |
| 10 | ad | + | - | - | + | - | 53.47 | 98.55 | -6.05 | -38.74 | 3.94 | 64.72 | AD | 1.011 |
| 11 | bd | - | + | - | + | - | 49.02 | 121.03 | -6.10 | -24.93 | 64.44 | 43.89 | BD | 0.686 |
| 12 | abd | + | + | - | + | - | 47.88 | 105.16 | -2.92 | -9.57 | -46.53 | -150.16 | ABD | -2.346 |
| 13 | cd | - | - | + | + | - | 54.74 | 123.44 | -8.55 | 92.67 | 26.59 | -13.09 | CD | -0.205 |
| 14 | acd | + | - | + | + | - | 55.63 | 118.07 | -22.73 | -0.89 | -5.63 | -76.25 | ACD | -1.191 |
| 15 | bcd | - | + | + | + | - | 45.21 | 114.81 | 0.72 | 51.60 | -45.38 | -36.11 | BCD | -0.564 |
| 16 | abcd | + | + | + | + | - | 41.40 | 110.62 | -31.62 | -5.00 | -45.08 | 70.73 | ABCD | 1.105 |
| 17 | e | - | - | - | - | + | 67.86 | -66.04 | -51.31 | -34.84 | -121.25 | -33.49 | E | -0.523 |
| 18 | ae | + | - | - | - | + | 39.75 | -1.27 | -15.96 | -11.81 | 34.59 | 20.19 | AE | 0.315 |
| 19 | be | - | + | - | - | + | 39.50 | -16.98 | -14.99 | 20.03 | 64.34 | 71.50 | BE | 1.117 |
| 20 | abe | + | + | - | - | + | 59.06 | 10.93 | -23.75 | -16.09 | 0.38 | -45.18 | ABE | -0.706 |
| 21 | ce | - | - | + | - | + | 67.18 | -4.95 | -9.06 | 61.26 | 28.53 | 50.59 | CE | 0.790 |
| 22 | ace | + | - | + | - | + | 53.85 | -1.14 | -15.88 | 3.18 | 15.36 | -110.96 | ACE | -1.734 |
| 23 | bce | - | + | + | - | + | 57.28 | 0.89 | -5.38 | -14.18 | -93.56 | -32.22 | BCE | -0.503 |
| 24 | abce | + | + | + | - | + | 47.88 | -3.81 | -4.19 | -32.34 | -56.60 | 0.29 | ABCE | 0.005 |
| 25 | de | - | - | - | + | + | 61.09 | -28.11 | 64.77 | 35.35 | 23.03 | 155.84 | DE | 2.435 |
| 26 | ade | + | - | - | + | + | 62.36 | 19.56 | 27.90 | -8.76 | -36.11 | -63.96 | ADE | -0.999 |
| 27 | bde | - | + | - | + | + | 59.31 | -13.34 | 3.81 | -6.82 | -58.09 | -13.17 | BDE | -0.206 |
| 28 | abde | + | + | - | + | + | 58.76 | -9.40 | -4.70 | 1.19 | -18.16 | 36.96 | ABDE | 0.578 |
| 29 | cde | - | - | + | + | + | 64.52 | 1.27 | 47.67 | -36.87 | -44.12 | -59.14 | CDE | -0.924 |
| 30 | acde | + | - | + | + | + | 50.29 | -0.55 | 3.94 | -8.51 | 8.00 | 39.93 | ACDE | 0.624 |
| 31 | bcde | - | + | + | + | + | 64.01 | -14.22 | -1.82 | -43.73 | 28.36 | 52.12 | BCDE | 0.814 |
| 32 | abcde | + | + | + | + | + | 46.61 | -17.40 | -3.18 | -1.36 | 42.37 | 14.02 | ABCDE | 0.219 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | DE | 2.435 | 0.9839 |
| 30 | AB | 2.162 | 0.9516 |
| 29 | BE | 1.117 | 0.9194 |
| 28 | ABCD | 1.105 | 0.8871 |
| 27 | AD | 1.011 | 0.8548 |
| 26 | BCDE | 0.814 | 0.8226 |
| 25 | CE | 0.790 | 0.7903 |
| 24 | BD | 0.686 | 0.7581 |
| 23 | ACDE | 0.624 | 0.7258 |
| 22 | ABDE | 0.578 | 0.6935 |
| 21 | BC | 0.327 | 0.6613 |
| 20 | AE | 0.315 | 0.6290 |
| 19 | AC | 0.280 | 0.5968 |
| 18 | ABCDE | 0.219 | 0.5645 |
| 17 | ABCE | 0.005 | 0.5323 |
| 16 | CD | -0.205 | 0.5000 |
| 15 | BDE | -0.206 | 0.4677 |
| 14 | BCE | -0.503 | 0.4355 |
| 13 | E | -0.523 | 0.4032 |
| 12 | BCD | -0.564 | 0.3710 |
| 11 | C | -0.667 | 0.3387 |
| 10 | ABE | -0.706 | 0.3065 |
| 9 | CDE | -0.924 | 0.2742 |
| 8 | ADE | -0.999 | 0.2419 |
| 7 | ACD | -1.191 | 0.2097 |
| 6 | D | -1.354 | 0.1774 |
| 5 | ABC | -1.413 | 0.1452 |
| 4 | ACE | -1.734 | 0.1129 |
| 3 | B | -2.195 | 0.0806 |
| 2 | A | -2.259 | 0.0484 |
| 1 | ABD | -2.346 | 0.0161 |

Table A-8: The $2^5$ factorial design of melting point temperature.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 250.83 | 502.17 | 1009 | 2016.0 | 4043.3 | 8058.7 |  |  |
| 2 | a | + | - | - | - | - | 251.34 | 506.54 | 1007 | 2027.3 | 4015.4 | -4.16 | A | -0.130 |
| 3 | b | - | + | - | - | - | 253.49 | 503.42 | 1017 | 2018.6 | -7.15 | -14.44 | B | -0.451 |
| 4 | ab | + | + | - | - | - | 253.05 | 503.87 | 1011 | 1996.7 | 2.99 | 1.48 | AB | 0.046 |
| 5 | c | - | - | + | - | - | 252.58 | 507.49 | 1010 | -1.94 | 4.45 | -18.64 | C | -0.583 |
| 6 | ac | + | - | + | - | - | 250.84 | 509.19 | 1009 | -5.21 | -18.89 | 8.92 | AC | 0.279 |
| 7 | bc | - | + | + | - | - | 252.07 | 506.36 | 1003 | 0.62 | -6.95 | -18.32 | BC | -0.573 |
| 8 | abc | + | + | + | - | - | 251.80 | 504.29 | 993.4 | 2.37 | 8.43 | -4.08 | ABC | -0.128 |
| 9 | d | - | - | - | + | - | 253.42 | 503.87 | 0.07 | 4.82 | -7.45 | -10.60 | D | -0.331 |
| 10 | ad | + | - | - | + | - | 254.07 | 506.10 | -2.01 | -0.37 | -11.19 | -1.52 | AD | -0.048 |
| 11 | bd | - | + | - | + | - | 255.95 | 509.57 | -2.06 | -8.24 | -3.17 | -7.60 | BD | -0.238 |
| 12 | abd | + | + | - | + | - | 253.24 | 499.10 | -3.15 | -10.65 | 12.09 | -9.28 | ABD | -0.290 |
| 13 | cd | - | - | + | + | - | 252.94 | 504.83 | -3.35 | 0.52 | -7.69 | -13.20 | CD | -0.412 |
| 14 | acd | + | - | + | + | - | 253.42 | 498.47 | 3.97 | -7.47 | -10.63 | -1.56 | ACD | -0.049 |
| 15 | bcd | - | + | + | + | - | 253.96 | 498.85 | -1.20 | 4.86 | 1.67 | 14.92 | BCD | 0.466 |
| 16 | abcd | + | + | + | + | - | 250.33 | 494.56 | 3.57 | 3.57 | -5.75 | -14.84 | ABCD | -0.464 |
| 17 | e | - | - | - | - | + | 253.01 | 0.51 | 4.37 | -1.42 | 11.33 | -27.98 | E | -0.874 |
| 18 | ae | + | - | - | - | + | 250.86 | -0.44 | 0.45 | -6.03 | -21.93 | 10.14 | AE | 0.317 |
| 19 | be | - | + | - | - | + | 253.65 | -1.74 | 1.70 | -1.30 | -3.27 | -23.34 | BE | -0.729 |
| 20 | abe | + | + | - | - | + | 252.45 | -0.27 | -2.07 | -9.89 | 1.75 | 15.38 | ABE | 0.481 |
| 21 | ce | - | - | + | - | + | 254.77 | 0.65 | 2.23 | -2.08 | -5.19 | -3.74 | CE | -0.117 |
| 22 | ace | + | - | + | - | + | 254.80 | -2.71 | -10.47 | -1.09 | -2.41 | 15.26 | ACE | 0.477 |
| 23 | bce | - | + | + | - | + | 247.58 | 0.48 | -6.36 | 7.32 | -7.99 | -2.94 | BCE | -0.092 |
| 24 | abce | + | + | + | - | + | 251.52 | -3.63 | -4.29 | 4.77 | -1.29 | -7.42 | ABCE | -0.232 |
| 25 | de | - | - | - | + | + | 254.25 | -2.15 | -0.95 | -3.92 | -4.61 | -33.26 | DE | -1.039 |
| 26 | ade | + | - | - | + | + | 250.58 | -1.20 | 1.47 | -3.77 | -8.59 | 5.02 | ADE | 0.157 |
| 27 | bde | - | + | - | + | + | 248.00 | 0.03 | -3.36 | -12.70 | 0.99 | 2.78 | BDE | 0.087 |
| 28 | abde | + | + | - | + | + | 250.47 | 3.94 | -4.11 | 2.07 | -2.55 | 6.70 | ABDE | 0.209 |
| 29 | cde | - | - | + | + | + | 247.89 | -3.67 | 0.95 | 2.42 | 0.15 | -3.98 | CDE | -0.124 |
| 30 | acde | + | - | + | + | + | 250.96 | 2.47 | 3.91 | -0.75 | 14.77 | -3.54 | ACDE | -0.111 |
| 31 | bcde | - | + | + | + | + | 247.03 | 3.07 | 6.14 | 2.96 | -3.17 | 14.62 | BCDE | 0.457 |
| 32 | abcde | + | + | + | + | + | 247.53 | 0.50 | -2.57 | -8.71 | -11.67 | -8.50 | ABCDE | -0.266 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | ABE | 0.481 | 0.9839 |
| 30 | ACE | 0.477 | 0.9516 |
| 29 | BCD | 0.466 | 0.9194 |
| 28 | BCDE | 0.457 | 0.8871 |
| 27 | AE | 0.317 | 0.8548 |
| 26 | AC | 0.279 | 0.8226 |
| 25 | ABDE | 0.209 | 0.7903 |
| 24 | ADE | 0.157 | 0.7581 |
| 23 | BDE | 0.087 | 0.7258 |
| 22 | AB | 0.046 | 0.6935 |
| 21 | AD | -0.048 | 0.6613 |
| 20 | ACD | -0.049 | 0.6290 |
| 19 | BCE | -0.092 | 0.5968 |
| 18 | ACDE | -0.111 | 0.5645 |
| 17 | CE | -0.117 | 0.5323 |
| 16 | CDE | -0.124 | 0.5000 |
| 15 | ABC | -0.128 | 0.4677 |
| 14 | A | -0.130 | 0.4355 |
| 13 | ABCE | -0.232 | 0.4032 |
| 12 | BD | -0.238 | 0.3710 |
| 11 | ABCDE | -0.266 | 0.3387 |
| 10 | ABD | -0.290 | 0.3065 |
| 9 | D | -0.331 | 0.2742 |
| 8 | CD | -0.412 | 0.2419 |
| 7 | B | -0.451 | 0.2097 |
| 6 | ABCD | -0.464 | 0.1774 |
| 5 | BC | -0.573 | 0.1452 |
| 4 | C | -0.583 | 0.1129 |
| 3 | BE | -0.729 | 0.0806 |
| 2 | E | -0.874 | 0.0484 |
| 1 | DE | -1.039 | 0.0161 |

Table A-9: The $2^5$ factorial design of percent crystallinity.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 113.74 | 231.71 | 472.18 | 939.8 | 1864.2 | 3700.0 | A | 0.740 |
| 2 | a | + | - | - | - | - | 117.97 | 240.47 | 467.61 | 924.4 | 1835.9 | 23.69 | B | -0.964 |
| 3 | b | - | + | - | - | - | 114.47 | 237.60 | 467.95 | 899.6 | 1.46 | -30.85 | AB | 0.393 |
| 4 | ab | + | + | - | - | - | 126.00 | 230.01 | 456.42 | 936.2 | 22.23 | 12.57 | C | -0.097 |
| 5 | c | - | - | + | - | - | 121.17 | 240.81 | 448.16 | 11.43 | -25.96 | -3.11 | AC | -0.295 |
| 6 | ac | + | - | + | - | - | 116.43 | 227.14 | 451.47 | -9.97 | -4.89 | -9.45 | BC | -0.417 |
| 7 | bc | - | + | + | - | - | 114.80 | 234.94 | 463.28 | 19.63 | 11.66 | -13.35 | ABC | 0.055 |
| 8 | abc | + | + | + | - | - | 115.21 | 221.48 | 472.96 | 2.60 | 0.91 | 1.75 | D | 0.662 |
| 9 | d | - | - | - | + | - | 121.64 | 223.30 | 15.76 | 1.17 | -16.10 | 21.19 | AD | -1.201 |
| 10 | ad | + | - | - | + | - | 119.17 | 224.86 | -4.33 | -27.13 | 12.99 | -38.43 | BD | -0.948 |
| 11 | bd | - | + | - | + | - | 115.52 | 227.23 | -6.37 | -1.43 | -17.32 | -30.33 | ABD | -0.406 |
| 12 | abd | + | + | - | + | - | 111.62 | 224.24 | -3.60 | -3.46 | 7.87 | -12.99 | CD | -0.018 |
| 13 | cd | - | - | + | + | - | 118.53 | 234.34 | 8.76 | 12.45 | -16.14 | -0.59 | ACD | 0.828 |
| 14 | acd | + | - | + | + | - | 116.41 | 228.94 | 10.87 | -0.79 | 2.79 | 26.51 | BCD | 0.889 |
| 15 | bcd | - | + | + | + | - | 111.48 | 235.51 | -1.58 | 0.33 | -0.08 | 28.45 | ABCD | -0.227 |
| 16 | abcd | + | + | + | + | - | 110.00 | 237.45 | 4.18 | 0.58 | 1.83 | -7.25 | E | -0.884 |
| 17 | e | - | - | - | - | + | 108.67 | 4.23 | 8.76 | -4.57 | -15.42 | -28.29 | AE | 0.649 |
| 18 | ae | + | - | - | - | + | 114.63 | 11.53 | -7.59 | -11.53 | 36.61 | 20.77 | BE | 0.658 |
| 19 | be | - | + | - | - | + | 111.03 | -4.74 | -13.67 | 3.31 | -21.40 | 21.07 | ABE | -0.336 |
| 20 | abe | + | + | - | - | + | 113.83 | 0.41 | -13.46 | 9.68 | -17.03 | -10.75 | CE | 0.909 |
| 21 | ce | - | - | + | - | + | 111.77 | -2.47 | 1.56 | -20.09 | -28.30 | 29.09 | ACE | 0.787 |
| 22 | ace | + | - | + | - | + | 115.46 | -3.90 | -2.99 | 2.77 | -2.03 | 25.19 | BCE | 0.592 |
| 23 | bce | - | + | + | - | + | 108.53 | -2.12 | -5.40 | 2.11 | -13.24 | 18.93 | ABCE | 0.060 |
| 24 | abce | + | + | + | - | + | 115.71 | -1.48 | 1.94 | 5.76 | 0.25 | 1.91 | DE | 1.626 |
| 25 | de | - | - | - | + | + | 118.24 | 5.96 | 7.30 | -16.35 | -6.96 | 52.03 | ADE | 0.137 |
| 26 | ade | + | - | - | + | + | 116.10 | 2.80 | 5.15 | 0.21 | 6.37 | 4.37 | BDE | 0.821 |
| 27 | bde | - | + | - | + | + | 114.19 | 3.69 | -1.43 | -4.55 | 22.86 | 26.27 | ABDE | 0.422 |
| 28 | abde | + | + | - | + | + | 114.75 | 7.18 | 0.64 | 7.34 | 3.65 | 13.49 | CDE | 0.417 |
| 29 | cde | - | - | + | + | + | 116.18 | -2.14 | -3.16 | -2.15 | 16.56 | 13.33 | ACDE | -0.600 |
| 30 | acde | + | - | + | + | + | 119.33 | 0.56 | 3.49 | 2.07 | 11.89 | -19.21 | BCDE | -0.146 |
| 31 | bcde | - | + | + | + | + | 118.21 | 3.15 | 2.70 | 6.65 | 4.22 | -4.67 | ABCDE | -0.490 |
| 32 | abcde | + | + | + | + | + | 119.24 | 1.03 | -2.12 | -4.82 | -11.47 | -15.69 | | |

| Order(i) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | DE | 1.626 | 0.9839 |
| 30 | CE | 0.909 | 0.9516 |
| 29 | BCD | 0.889 | 0.9194 |
| 28 | ACD | 0.828 | 0.8871 |
| 27 | BDE | 0.821 | 0.8548 |
| 26 | ACE | 0.787 | 0.8226 |
| 25 | A | 0.740 | 0.7903 |
| 24 | D | 0.662 | 0.7581 |
| 23 | BE | 0.658 | 0.7258 |
| 22 | AE | 0.649 | 0.6935 |
| 21 | BCE | 0.592 | 0.6613 |
| 20 | ABDE | 0.422 | 0.6290 |
| 19 | CDE | 0.417 | 0.5968 |
| 18 | AB | 0.393 | 0.5645 |
| 17 | ADE | 0.137 | 0.5323 |
| 16 | ABCE | 0.060 | 0.5000 |
| 15 | ABC | 0.055 | 0.4677 |
| 14 | CD | -0.018 | 0.4355 |
| 13 | C | -0.097 | 0.4032 |
| 12 | BCDE | -0.146 | 0.3710 |
| 11 | ABCD | -0.227 | 0.3387 |
| 10 | AC | -0.295 | 0.3065 |
| 9 | ABE | -0.336 | 0.2742 |
| 8 | ABD | -0.406 | 0.2419 |
| 7 | BC | -0.417 | 0.2097 |
| 6 | ABCDE | -0.490 | 0.1774 |
| 5 | ACDE | -0.600 | 0.1452 |
| 4 | E | -0.884 | 0.1129 |
| 3 | BD | -0.948 | 0.0806 |
| 2 | B | -0.964 | 0.0484 |
| 1 | AD | -1.201 | 0.0161 |

Table A-10: The $2^5$ factorial design of heat deflection temperature.

| Run Number | Factorial Code | A | B | C | D | E | Sum of Response | (1) | (2) | (3) | (4) | (5) | Contrast | Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | - | - | - | - | - | 332.10 | 699.80 | 1434.40 | 3043.30 | 6366.60 | 12864.3 | | |
| 2 | a | + | - | - | - | - | 367.70 | 734.60 | 1608.90 | 3323.30 | 6497.70 | 321.90 | A | 5.030 |
| 3 | b | - | + | - | - | - | 365.20 | 786.00 | 1634.80 | 3132.70 | 174.80 | 271.70 | B | 4.245 |
| 4 | ab | + | + | - | - | - | 369.40 | 822.90 | 1688.50 | 3365.00 | 147.10 | -80.30 | AB | -1.255 |
| 5 | c | - | - | + | - | - | 380.90 | 794.80 | 1501.10 | 91.10 | 119.80 | 450.10 | C | 7.033 |
| 6 | ac | + | - | + | - | - | 405.10 | 840.00 | 1631.60 | 83.70 | 151.90 | -49.90 | AC | -0.780 |
| 7 | bc | - | + | + | - | - | 397.90 | 842.80 | 1636.80 | 101.50 | -30.00 | -134.10 | BC | -2.095 |
| 8 | abc | + | + | + | - | - | 425.00 | 845.70 | 1728.20 | 45.60 | -50.30 | 113.10 | ABC | 1.767 |
| 9 | d | - | - | - | + | - | 380.20 | 716.40 | 39.80 | 71.70 | 228.20 | 512.30 | D | 8.005 |
| 10 | ad | + | - | - | + | - | 414.60 | 784.70 | 51.30 | 48.10 | 221.90 | -63.30 | AD | -0.989 |
| 11 | bd | - | + | - | + | - | 410.60 | 798.70 | 53.20 | 102.50 | -11.20 | -76.70 | BD | -1.198 |
| 12 | abd | + | + | - | + | - | 429.40 | 832.90 | 30.50 | 49.40 | -38.70 | 0.50 | ABD | 0.008 |
| 13 | cd | - | - | + | + | - | 417.30 | 791.10 | 63.90 | -28.50 | -40.20 | -159.90 | CD | -2.498 |
| 14 | acd | + | - | + | + | - | 425.50 | 845.70 | 37.60 | -1.50 | -93.90 | -20.30 | ACD | -0.317 |
| 15 | bcd | - | + | + | + | - | 411.70 | 866.70 | 29.00 | -11.90 | 64.00 | -70.10 | BCD | -1.095 |
| 16 | abcd | + | + | + | + | - | 434.00 | 861.50 | 16.60 | -38.40 | 49.10 | 79.10 | ABCD | 1.236 |
| 17 | e | - | - | - | - | + | 342.90 | 35.60 | 34.80 | 174.50 | 280.00 | 131.10 | E | 2.048 |
| 18 | ae | + | - | - | - | + | 373.50 | 4.20 | 36.90 | 53.70 | 232.30 | -27.70 | AE | -0.433 |
| 19 | be | - | + | - | - | + | 375.70 | 24.20 | 45.20 | 130.50 | -7.40 | 32.10 | BE | 0.502 |
| 20 | abe | + | + | - | - | + | 409.00 | 27.10 | 2.90 | 91.40 | -55.90 | -20.30 | ABE | -0.317 |
| 21 | ce | - | - | + | - | + | 386.30 | 34.40 | 68.30 | 11.50 | -23.60 | -6.30 | CE | -0.098 |
| 22 | ace | + | - | + | - | + | 412.40 | 18.80 | 34.20 | -22.70 | -53.10 | -27.50 | ACE | -0.430 |
| 23 | bce | - | + | + | - | + | 410.70 | 8.20 | 54.60 | -26.30 | 27.00 | -53.70 | BCE | -0.839 |
| 24 | abce | + | + | + | - | + | 422.20 | 22.30 | -5.20 | -12.40 | -26.50 | -14.90 | ABCE | -0.233 |
| 25 | de | - | - | - | + | + | 375.20 | 30.60 | -31.40 | 2.10 | -120.80 | -47.70 | DE | -0.745 |
| 26 | ade | + | - | - | + | + | 415.90 | 33.30 | 2.90 | -42.30 | -39.10 | -48.50 | ADE | -0.758 |
| 27 | bde | - | + | - | + | + | 428.70 | 26.10 | -15.60 | -34.10 | -34.20 | -29.50 | BDE | -0.461 |
| 28 | abde | + | + | - | + | + | 417.00 | 11.50 | 14.10 | -59.80 | 13.90 | -53.50 | ABDE | -0.836 |
| 29 | cde | - | - | + | + | + | 432.70 | 40.70 | 2.70 | 34.30 | -44.40 | 81.70 | CDE | 1.277 |
| 30 | acde | + | - | + | + | + | 434.00 | -11.70 | -14.60 | 29.70 | -25.70 | 48.10 | ACDE | 0.752 |
| 31 | bcde | - | + | + | + | + | 423.10 | 1.30 | -52.40 | -17.30 | -4.60 | 18.70 | BCDE | 0.292 |
| 32 | abcde | + | + | + | + | + | 438.40 | 15.30 | 14.00 | 66.40 | 83.70 | 88.30 | ABCDE | 1.380 |

| Order(j) | Code | Effect | Pk=(j-0.5)/31 |
|---|---|---|---|
| 31 | D | 8.005 | 0.9839 |
| 30 | C | 7.033 | 0.9516 |
| 29 | A | 5.030 | 0.9194 |
| 28 | B | 4.245 | 0.8871 |
| 27 | E | 2.048 | 0.8548 |
| 26 | ABC | 1.767 | 0.8226 |
| 25 | ABCDE | 1.380 | 0.7903 |
| 24 | CDE | 1.277 | 0.7581 |
| 23 | ABCD | 1.236 | 0.7258 |
| 22 | ACDE | 0.752 | 0.6935 |
| 21 | BE | 0.502 | 0.6613 |
| 20 | BCDE | 0.292 | 0.6290 |
| 19 | ABD | 0.008 | 0.5968 |
| 18 | CE | -0.098 | 0.5645 |
| 17 | ABCE | -0.233 | 0.5323 |
| 16 | ABE | -0.317 | 0.5000 |
| 15 | ACD | -0.317 | 0.4677 |
| 14 | ACE | -0.430 | 0.4355 |
| 13 | AE | -0.433 | 0.4032 |
| 12 | BDE | -0.461 | 0.3710 |
| 11 | DE | -0.745 | 0.3387 |
| 10 | ADE | -0.758 | 0.3065 |
| 9 | AC | -0.780 | 0.2742 |
| 8 | ABDE | -0.836 | 0.2419 |
| 7 | BCE | -0.839 | 0.2097 |
| 6 | AD | -0.989 | 0.1774 |
| 5 | BCD | -1.095 | 0.1452 |
| 4 | BD | -1.198 | 0.1129 |
| 3 | AB | -1.255 | 0.0806 |
| 2 | BC | -2.095 | 0.0484 |
| 1 | CD | -2.498 | 0.0161 |

# VITA

Mr. Verasak Coodtapan was born in Chonburi, Thailand on March 7, 1971. He graduated high school from Chonrasadon Aumrung School in 1987 and recived a Bachelor of Science in Industrial Chemistry from the Department of Chemistry, Faculty of Science, King Mongkut's Institute of Technology Ladkrabang in 1991. Recently, he is studing of Master's Degree in Chemical Engineering at Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University.