

2.4.1 Design Of Experiments (DOE)

1. Definition

Experimentation is a systematic approach to answer questions and more specifically; how do changes to a system actually affect the quality function or response of the system?

Whenever we adjust a process or a product without knowing what the outcome will be, we are making **experiments**.

Experiments come in many forms and can be categorized as followed:

1.1 Trial and Error Experiment

Most experiments are TRIAL AND ERROR experiment involving one or two variables. When an operator makes adjustment to a process, checks the result and repeats this until the desired result is obtained, he is conducting a trial and error experiment.

1.2 One by One Experiment

When a team can collect more variables around the members are convinced to start changing only one variable at a time. In this way, team is able to isolate each variable effect. This method is called the ONE-by-ONE experiment. No interacting effect could be captured via this conventional ways of conducting experimentation.

1.3 Design-of-experiments (DOE)

When we have more variables at different levels, we will need a more structural method of doing the experiments, intelligently, efficiently at a low cost, thus team must design their experiments. A structured DOE also means that interacting effects among individual factors can be captured. Since the study/understanding of interaction is a vital to initial stages of any experimentation, its is always advisable to perform proper DOE than to do one by one experimentation.

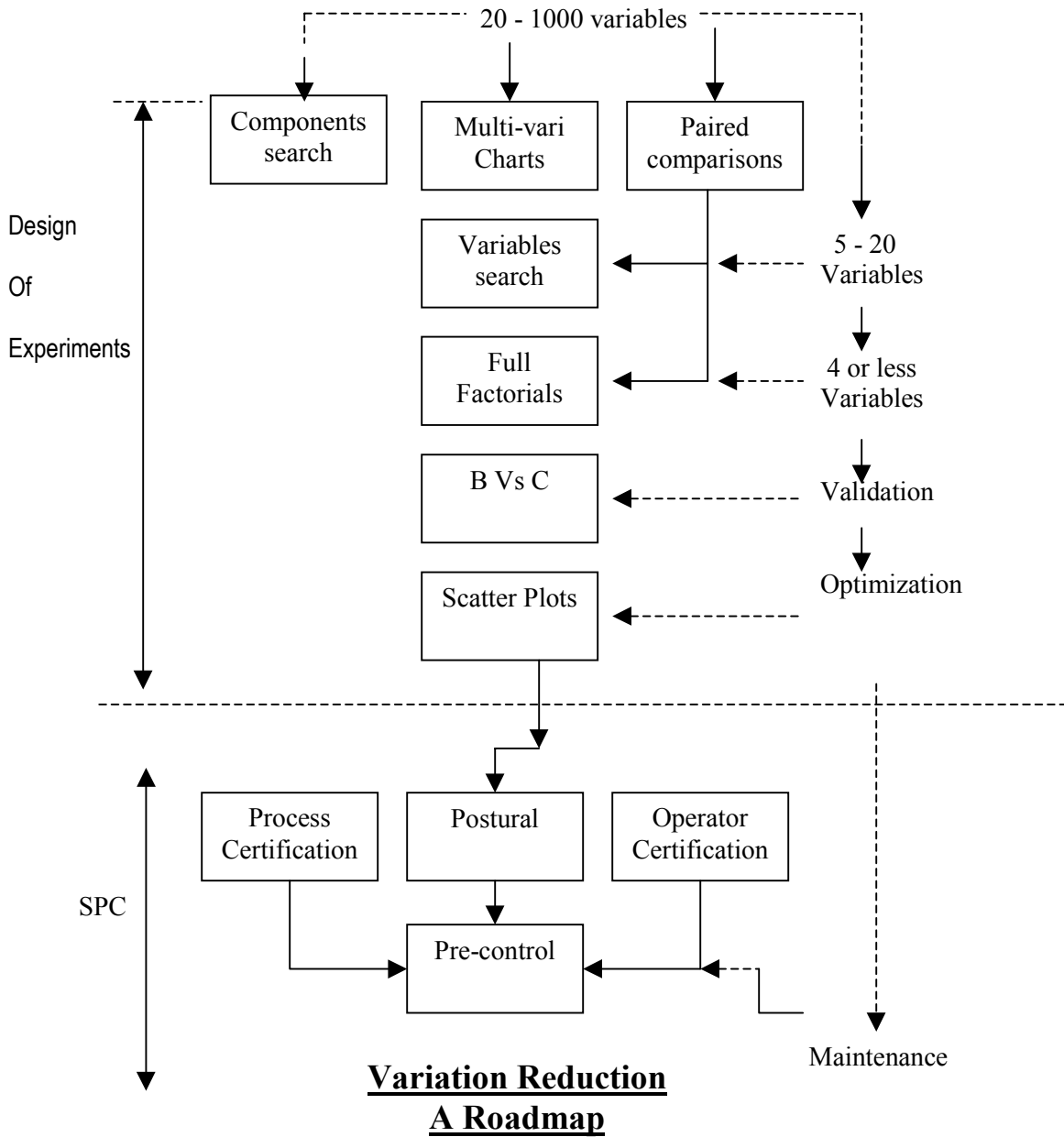
2. Objectives

The Design of experiment can assist the team to

- 2.1 identify the important causes or variables whether they are product or process parameters, materials, and environmental or measuring equipment factors.
- 2.2 Determine the main effects and interaction effects of these important variables.
- 2.3 Reduce the variation on the important variables through close tolerancing, re-design improve component.
- 2.4 Open the tolerance on the unimportant variables to reduce costs substantially.

3. Application.

- Steps at a glance for Shainin's DOE.



3.1 The team will have to communicate the experimental objective to everyone involved before the application of the Design of Experiments.

3.2 The three types of Design of Experiments can be classified as followed :

3.2.1 Classical

3.2.2 Taguchi

3.2.3 Shainin

3.3 A comparison of the above three types of DOE are as followed :

Characteristics	Classical	Taguchi	Shainin
Technique	- Fractional factorials	- Orthogonal arrays	- Multi-vari, variable searches full factorials.
Effectiveness	- Moderate (20% to 200% improvement) - Retrogression possible	- Low to moderate (20% to 100% improvement) - Retrogression likely	- Extremely powerful (100% to 500% improvement) - No retrogression
Cost	- Moderate - Average of 50 experiments	- High - Average 50 to 100 experiments	- Low - Average of 20 experiments
Complexity	- Moderate - Full ANOVA required	- High - Inner and outer array multiplication S/N, ANOVA	- Low - Experiments can be understood by line operators
Statistical validity	- Low - Higher order interaction effects confounded with main effects - To lesser extend even 2 nd order interaction effects confused	- Poor - No randomization - Even 2 nd order interaction effect confounded with main effects	- High - Every variable tested with all levels of every other variable - Excellent separation and qualification of main interaction effects.
Applicability	- Requires hardware - Main use in production	- Primary use as a substitute for Monte Carlo analysis	- Requires hardware - Can be use as early as prototype and engineering run stage. -

QTM - QUALITY TOOLS' MANUAL.

Ease of implementation	- moderate - engineering and statistical knowledge required.	- Difficult - Engineers not likely to use this method.	- Easy
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3.4 The application of Shainin (DOE) using the 7 DOE Quality Tools are as followed :

3.4.1 Multi-Vari-Chart

3.4.1 a) The multi-vari chart is to graphically depict family of variation patterns that will enable you to reduce a large number of unmanageable possible causes (variation) to a much smaller family of variables containing the Red X.

- Detect large non-random variables
- Detect variables containing the Red X

3.4.1 b) The three families of variation depicted in the multi-vari charts are:

- Positional variation
- Cyclical variation
- Temporal (time) variation

3.4.1 c) When using the multi-vari data, team is able to locate the family that shows the largest variation. This is the family that will contain the previously unidentified major variable, the Xs.

3.4.1 d) Although all families may contribute in some way to the overall variability in the process, they generally do not contribute equally.

- Positional Variation

The positional family of variation depicts variations in a product position. This positional variation can occur with a single unit containing one single characteristic or more than one variation within a single unit.

- variation within or across a single unit
- variation by location
- machine to machine variations

- Cyclical Variation

- variation between consecutive units
- variation among groups of units
- variation between batch to batch

- Temporal (Time) variation

- hour to hour variation
- shift to shift variation
- day to day variation
- week to week variation

3.4.1 e) Examples of Multi- Vari Chart (reference to attached Appendix)

3.4.2 Component Search

3.4.2 a) Component search is another simple but powerful technique whereby a large number of possible causes of variation can be reduced to the family of the Red X or the Red X itself. Reduction to the lowest number of possible causes is the objective.

3.4.2 b) The technique is applicable, primarily in assembly operations (but also in process-oriented operations where, there are several similar processes or machines), where the longer the difference in output between the two units, the better.

- 3.4.2 c) The response (output/quality characteristics) must be measurable and repeatable.
- 3.4.2 d) The units must be capable of disassemble and re-assembled without a significant change in the original output.
- 3.4.2 e) There must be at least the assemblies or units with clearly different levels of output; for brevity, the two assemblies are described as a pair, a good unit and a bad unit.
- 3.4.2 f) The procedure for the component search are as followed:
- i) determine the response (output) parameter by which units are to be measured.
 - ii) select the best and worst-performing unit from your production, if possible have a few pairs
 - iii) label all the units, the Best units being B1, B2, B3 and the corresponding Worst units W1, W2 and W3
 - iv) Based upon engineering knowledge or consultation with designer rank the components in descending order of perceived importance.
 - v) measured pair #1 and note the reading

E.g. component reading
 B₁ X₁
 W₁..... Y₁

- vi) disassemble those components listed and reassemble the units measure both units and note the readings.

component	reading
B ₁	X ₂
W ₁	Y ₃

- vii) disassemble those components listed and reassemble the units measure both units and note the readings

component	reading
B ₁	X ₃
W ₁	Y ₃

- viii) All the three B₁ readings must rank better than all the three **Worst units**. Calculate the D: d ration. If the ratio is greater or equal the ratio 1.25 : 1, then the Red X and Pink X are among the causes being considered and there is good repeatability in the disassembly/assembly process.

- ix) Switch the top rank component from the good unit and the corresponding component in the bad assembly between the two assemblies.

- x) If there's no chance, i.e. the **Best unit** stays good and the **Worst unit** stay bad within the calculated control limits, this component A is unimportant. Switches back the component and proceed to the next component B.

- xi) If there is a partial change out of the control limits for one or both of the two assembly outputs, A is not the only important variable. A is important but not alone.

- xii) Further, A's interaction effect with other components cannot be needed out. Switches back the component A and go to the next component B.
- xiii) If there were a complete reversal in the outputs of the two assemblies, A would be the part having a Red X quality characteristics. Switches back the component A and go to the next component B.
- xiv) Repeat until the component list is completed.
- xv) Ultimately, the RED X family involving two or more components will be indicated. If there are two for more significant changes, A RED X interaction could be found at a later stage.
- xvi) With the important components identified, a capping run of these important components banded together in the good and worst assemblies must be conducted to verify the importance.
- xvii) Repeat the capping run with another two or three pairs, to verify that the first pair is not a fluke shot.

The test for significant and repeatable difference

- Measured pair #1 and note the reading

B₁... X₁
N₁... Y₁

- Disassemble those components listed and reassemble both units. Measure both units and note the readings.

$$\begin{array}{l} B_1 \dots X_1 \\ W_1 \dots Y_1 \end{array}$$

- Disassemble those components listed and reassembled both units. Measure both units and note the readings.

$$\begin{array}{l} B_1 \dots X_2 \\ W_1 \dots Y_2 \end{array}$$

- Disassemble those components listed and reassembled both units again. Measure both units and note the readings.

$$\begin{array}{l} B_1 \dots X_3 \\ W_1 \dots Y_3 \end{array}$$

$$D = \frac{(X_1 + X_2 + X_3)}{3} - \frac{(Y_1 + Y_2 + Y_3)}{3}$$

$$d = \frac{(\text{highest X} - \text{lowest X}) + (\text{highest Y} - \text{lowest Y})}{2}$$

Example.

Initial

- 1st disassembly and assembly
- 2nd disassembly and assembly

X		Y
9.8	dB	6
9.7	dB	5.8
10.2	dB	5.7

$$\begin{aligned}
 D &= \frac{(X_1 + X_2 + X_3)}{3} - \frac{(Y_1 + Y_2 + Y_3)}{3} \\
 &= \frac{(9.8 + 9.7 + 10.2)}{3} - \frac{(5.7 + 5.8 + 6)}{3} \\
 &= 9.9 - 5.8333 \\
 &= 4.066
 \end{aligned}$$

$$\begin{aligned}
 d &= \frac{(\text{highest X} - \text{lowest X}) + (\text{highest Y} - \text{lowest Y})}{2} \\
 &= \frac{(10.2 - 9.7) + (6.0 - 5.7)}{2} = 0.4
 \end{aligned}$$

Thus D: d is 10.1666: 1, which is greater than 1.25: 1
 Indicating that the Xs' are captured.

- Control limits

Control limits are used to determine whether a component and its associated interaction effects are important (outside of control limits) or unimportant (inside the control limits) and eliminated.

The control limits for each new swapped result are given by the formula

$$\text{Control limits} = \text{Average} \pm \{A_2 * \text{average range}\}$$

With three units of two samples (good and worst), A_2 is 1.023. From the example the control limits for the good units are

$$\begin{aligned} &= \text{average } (X_1 + X_2 + X_3) \pm 1.023 * (\text{average range}) \\ &= \text{average } (9.8 + 9.7 + 10.2) \pm 1.023 * (0.4) \\ &= 9.9 \pm 1.3299 \end{aligned}$$

$$\text{UCL} = 11.2299$$

$$\text{LCC} = 8.5701$$

For the worst units the control level is

$$\begin{aligned} &= \text{average } (Y_1 + Y_2 + Y_3) \pm 1.023 * (\text{average range}) \\ &= \text{average } (6.0 + 5.8 + 5.7) \pm 1.023 * (1.3) \\ &= 5.833 \end{aligned}$$

$$\text{UCL} = 7.16323$$

$$\text{LCL} = 4.50343$$

- Component to be searched

<u>Component</u>	<u>Label</u>	<u>Component</u>	<u>Label</u>
C2503	A	C2412	
G			
C2505	B	T7501	
H			
C2504	C	C2425	I
L5501	D	C2502	
J			
L5407	E	C2501	
K			
C2426	F	L5406	
L			

- Construct the component search chart

12	_____
11	_____
10	_____
9	_____
8	_____
7	_____
6	_____
5	_____
4	_____
	A B C D E F G H I J K

Note: X Interchange between Good and Worst unit
 O Return to original unit

- Test result

The graphical representation of result shows the clear separation between the original high (good) and low (worst) assemblies.

The graph shows a partial conveyance between the high and low assemblies when components

C (C2504) and E (L5407) is switched. The contributions of the remaining components are minor or zero?

In the capping run, when both the Pink X components, C and E are switched, there is a reversal in the result, indicating that the family of the RED X is a narrowed down to C and E, that are other components are unimportant for this parameter.

3.4.3 Paired Comparisons.

3.4.3 a) The pair comparison method is similar to components

search with the objective of reducing a large number of possible causes of operation down to the family of the RED X by providing clues derived from comparisons of paired "Good" and "Bad" units.

3.4.3 b) The technique is applicable in assembly work or processes

or in test equipment, where there are similar units, workstations or instruments, respectively. It is also a powerful tool in failure analysis.

3.4.3 c) The pre-requisites of paired comparisons

- Components or sub-assemblies in units cannot be disassembled or re-assembled (unlike component search)
- There are several good and few bad units that can be paired.

- A suitable output can be found to distinguish good from bad.

3.4.3 d) The procedure for paired comparisons

- i) Select one good unit and one bad unit (drawn whenever possible at the same time)
- ii) Call this pair one. Observe in detail to note differences between these two units. The difference can be visual, dimensional, electrical, mechanical, chemical, etc. The observation techniques could involve the eye, measurable parameters, X-rays...
- iii) Select a second pair of good and bad units. Observe and note the difference as in Step 2.
- iv) Repeat the search process with a third, fourth, fifth and sixth pair.
- v) If it is a measurable output, rank all the six pairs in descending orders. If the END Count is greater than six are then the output or that part that is contributing to the output is a possible X.
- vi) If it is an observable output (physical), then summarized all difference observed for all the six pairs. From the list, count the numbers of observable, repeatable difference between the good and the bad units.

Note: disregard differences that show contrary directions among the pairs.

With this, the consistent differences will be narrowed down to a few factors, providing a strong clue for the major cause of variation.

Example: UV 1216 D/P Crackle

End Count
According to Turkey Test

End Count	Confidence Level
5	81%
6	90%
7	95%
10	99%
13	99.9%

Example:

B1	48.0
B2	46.5
B3	46.9
B4	47.6
B5	48.3
B6	45.7
W1	42.7
W2	43.6
W3	46.7
W4	44.6
W5	45.9
W6	44.9

Ranking:

B5	48.3
B1	48.0
B4	47.6
B3	46.9
B2	46.5
W3	46.7
W5	45.9
B6	45.7
W6	44.9

W4	44.6
W2	43.6
W1	42.7

Total end count = 9 thus confidence is greater than 95% but less than 99%

3.4.4 Variables search

- 3.4.4 a) The systematic reduction of variation starts with
- Multi-vari chart
 - Components search
 - Paired comparison

- 3.4.4 b) The aim to reduce a very large number of unrelated causes
down to a smaller family of related causes where
variable search is the next tools where it's objectives
are

- To pin-point the RED X
- To pin-point the PINK X
- To pin-point interacting variables
- Separate the important variables from the unimportant ones

- 3.4.4 c) The pre-requisites of the variable search are
- When there are 5 to 10 variables to be investigated
 - Output preferable to be measurable
 - Quantifiable BEST and WORST event

- 3.4.4 d) The procedures for the variable search

- i) List the most important factors A, B, C, D, E, Fand so on in descending orders of importance. The listed factors are usually derived from the Multi-vari charts,

component search or paired comparisons. However, if the product is new, then conduct a brainstorming session, using all the expertise you can organize.

- ii) Assign two levels to each factor
 - a High (-), which is most likely to contribute to good or even best results.
 - A Low (-), which represents a most likely deviation from the HIGH level in day-to-day production with normal maintenance
- iii) Run two experiments, one with all factors at their high levels, the other with all at their low levels. Repeat these two experiments. Twice more randomize the experiments.
- iv) Apply the (D: d) greater than (1.25: 1) rule.
- v) Stage A is over when both stated below are satisfied.
 - all three high levels are better than three low levels
 - the (D : d) ratio is greater than 1.25

If all three high levels are worse than all three low levels just change the "High" and "Low" assignment.

- vi) If either of the two conditions in the earlier step is not met, then switch the level of one factor, generally if the factors have been carefully selected this step is not necessary.
 - vii) If the repeatability is poor, it is an indication than an important factor has been left out. Look for a clue from the previous experiments for one or more factors to be adopted and to re-run the tests.
- 1) Map out the experiments to be conducted

Test	Combination	Result	Average
1	A _{low} B _{high}		
2	A _{high} R _{low}		
3	B _{low} R _{high}		

4	B_{high}	R_{low}		
5	C_{low}	R_{high}		
6	C_{high}	R_{low}		

- 2) Run "test #1" i.e. with the low level of factor A, labeled A (low) along with the high levels of all the remaining factors R (high) record result.
- 3) Repeat #2 until all tests listed are completed.
- 4) Possible results
 - a) if both pairs of test - i.e. A (low) R (high) and A (high) R (low) - show result similar to the result C of the all-low and all-high respectively, then factor A, along with it's associated interaction effects is unimportant and can be eliminated.
 - b) if there is a complete reversal, i.e. if A (low) R (high) becomes the original all-high level and A (high) R (low) becomes the original all-low level, factor A is a main effect RED X.
 - c) if either or both pairs of tests, A (low) and A (high) R (low) shows only a slight change in level but not a complete reversal, factor A along with its associated interaction effects cannot be eliminated. Factor A and other factor or factors must be considered.

Example:

All high

All low

Initial	4	47
First	4	61
Second	3	66
Average	4	58

Test	Combination	Result	Average	Remarks
1	A _{low} R _{high}	23	4	Factor A input
2	A _{high} R _{low}	40	58	With other factor
3	B _{low} R _{high}	3	4	Factor B not
4	A _{low} R _{low}	61	58	Important
5	C _{low} R _{high}	46	4	Factor C important
6	C _{high} R _{low}	15	58	With other factor

Capping Run

If factors A and C display a partial reversal, run a capping run with these factors A_{high}, C_{low}, R_{low} and A_{low}, C_{high}, R_{high} to see if R, the rest of the factors can be eliminated.

One or more results showing partial switch, would indicate that the search is not yet complete, which is very rare, run a three factor capping.

3.4.5 Full factorials

3.4.5 a) The full factorials experiments are to pin point the most

important variables following the homing-in techniques, clue-generating techniques of Multi-Vari charts, components search, pair's comparison and variables search.

3.4.5 b) The full factorials also separate and quantify the main and

interaction effects of the important variables. The testing chosen factors with all levels (generally two) of every other variable. Thus, all possible combination of factors and levels are tested.

- 3.4.5 c) The pre-requisites of full factorial.
- When there are four or less factors.
 - Output variable to be measurable.
 - Two levels to be assigned (-), usually for the current level and (+) for the better result level.
 - Know the number of experiments that must be conducted by

$$C = L^P$$

Where C = nos. of experiments
(combination)

L = nos. of level

P = nos. of factors

Example: If there are 3 factors having 2 levels,
how

many combinations are there?

$$\begin{array}{l} L = 2 \quad \text{therefore} \quad C = 2^3 \\ P = 3 \quad \quad \quad \quad \quad = 8 \end{array}$$

- 3.4.5 d) The procedures for full factorial.
- 1) Use the factor based on previous homing-in experiments.
 - 2) Determine two levels of each factor, the first level labeled (-) is usually, but not necessarily the current level.
The second level, labeled (+) is assumed to produce better results but again not necessarily so.
 - 3) Draw up a matrix showing the combinations by which each factor is tested with each level of every other factor. Number each cell.

- 4) Randomized the sequence of experiments of each cell, as indicated by the random order table and read the output of each cell.
- 5) Repeat Step #4 using another random order for the second test sequence (the full set of experiments can be repeated for a few times if the experiments is not difficult to execute).
- 6) Calculate the average of the readings in each cell.
- 7) Add all the average readings in each cell where "A" is (-) and all the average cell readings where "A" is (+). The difference between A(-) and A(+) is due to factor A alone because all other factor B, C, and D balance one another i.e. have added, or subtracted, a constant or from both levels thereby not changing the original differences.
- 8) Repeat Step #7 for other factors.
- 9) Construct an Analysis of Variance (ANOVA) table.
- 10) For the "Factors" column enter the appropriate sign (-) or (+) as appear in the cell number.
- 11) For the "2 factors interactions", multiply algebraically the Signs of A and B in cell #1 and record the sign of product in the AB column. Here A & B are both (-). The product sign for AB is therefore (+). Repeat for the rest of the interactions.
- 12) In the "output" column, enter the average of the outputs recorded in each cell.
- 13) In the last row, assign the signs under column A to the output column and record the sum under column A.

14) Repeat Step 13 for the rest of the column.

15) The last row now displays, in precise quantified form the contribution of each column (main effect, interaction effect) to the total variation.

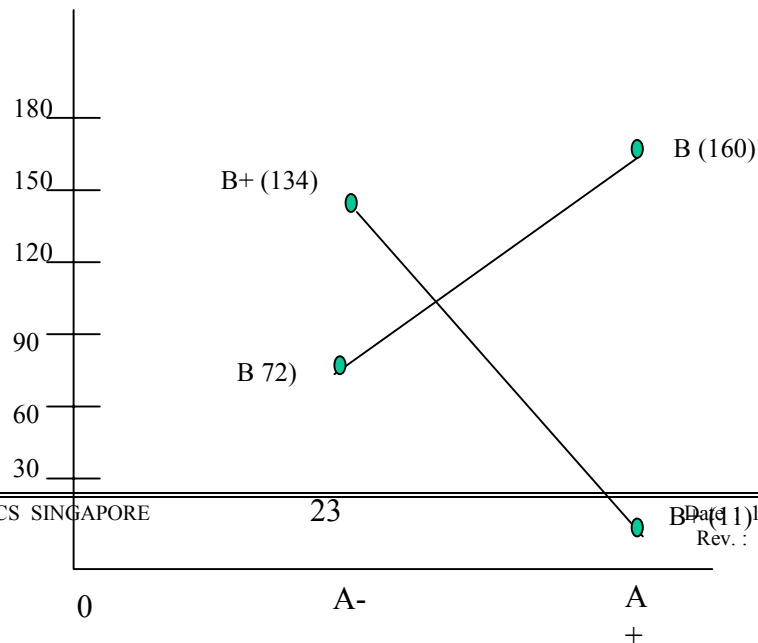
16) Interpretation of the result from table :

- select from the last row, the top two highest numbers disregard the sign at this moment of selection
 -The RED X interaction between the factors A and B
 - The PINK X interaction between the factors A and D

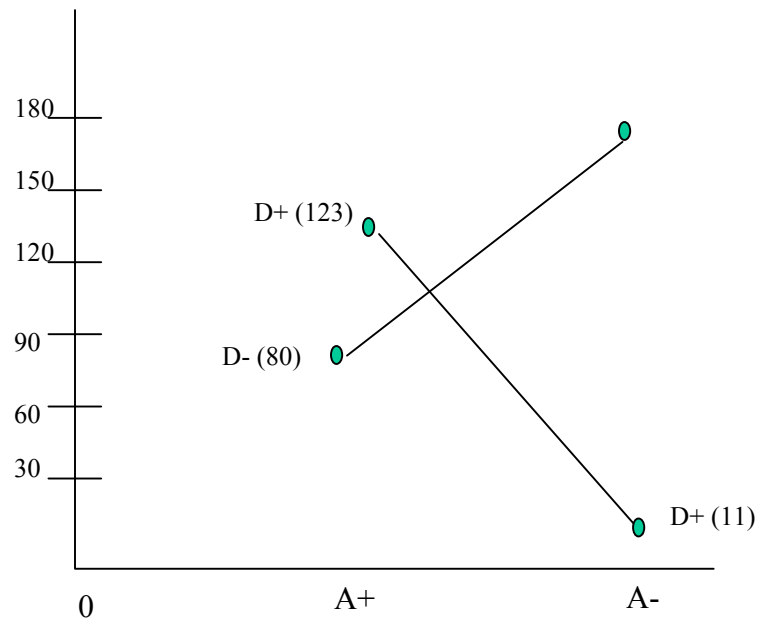
The main effects of A, B, C and D are relatively small compared to the interaction effects.

17) Interaction effect

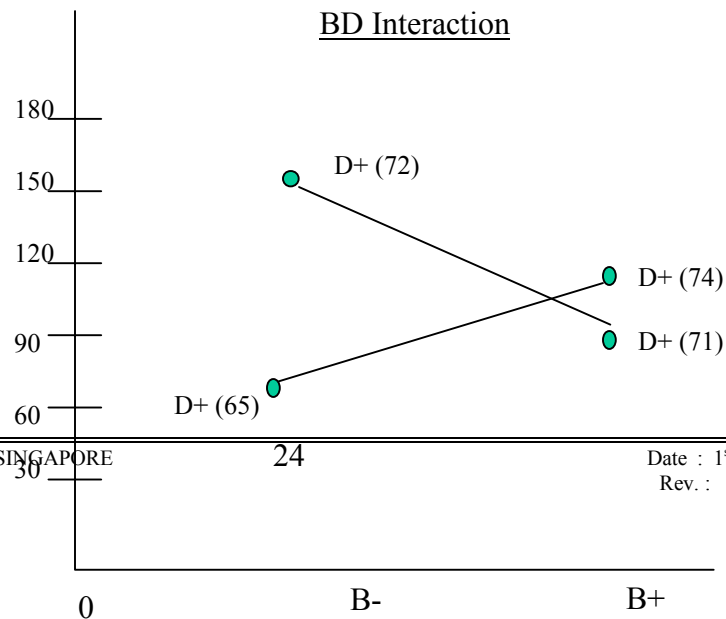
- a) For AB interaction
 - Example: Add all the output of those cells when both A and B are (-) i.e. $19 + 4 + 16 + 33$ which equals to 72.



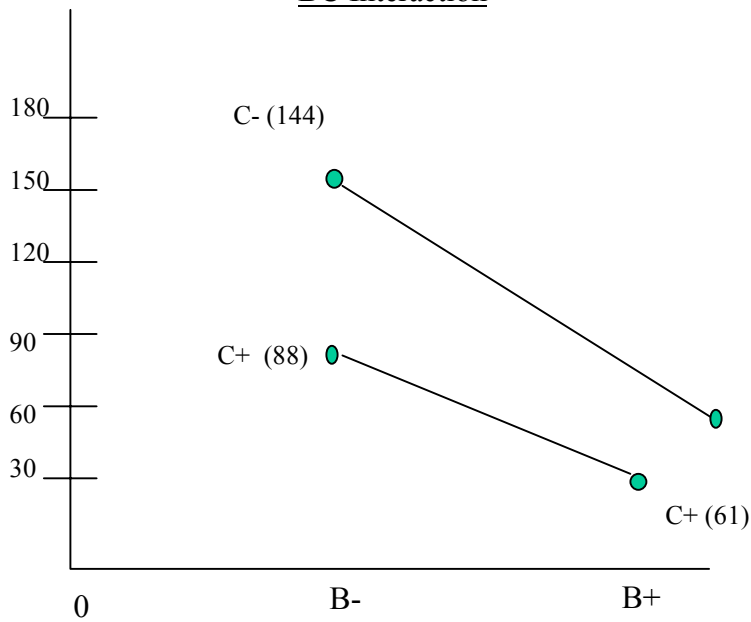
AD interaction



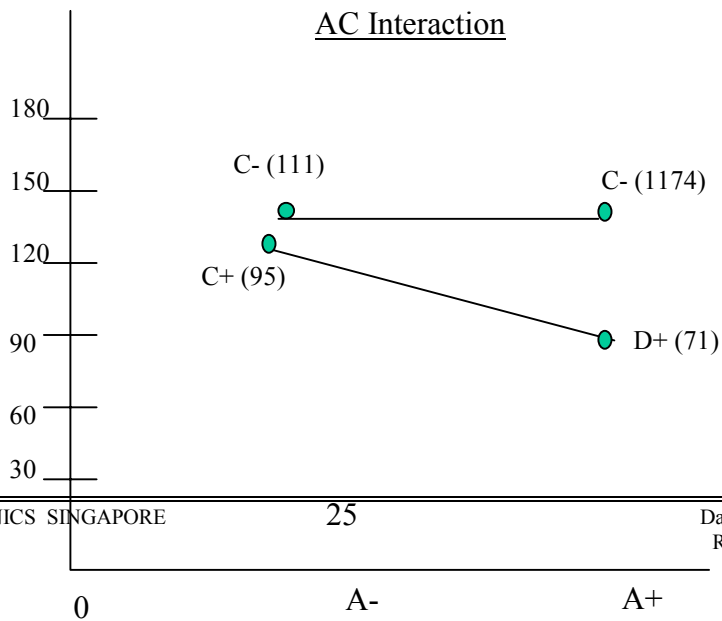
BD Interaction

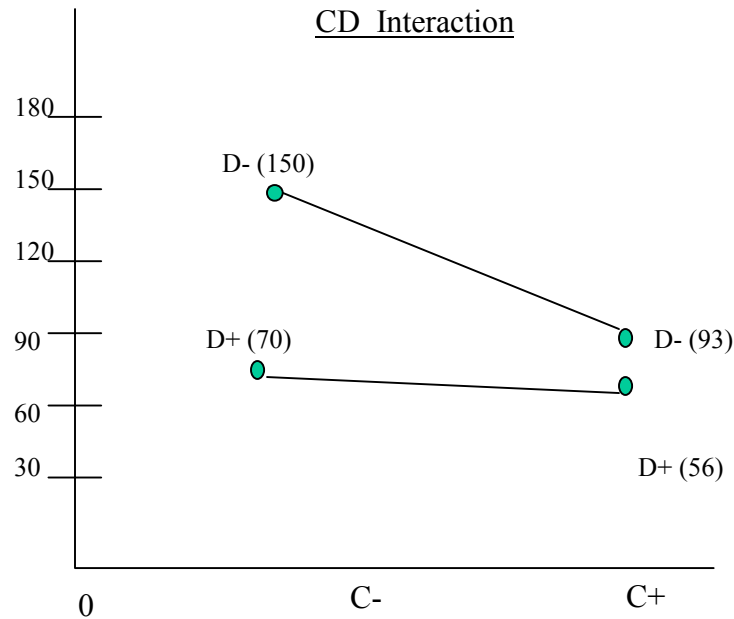


BC Interaction



AC Interaction





18) The interpretation of the interaction graphs

- From the AB and AD interaction graphs, the best results occur when A is (+). This is confirmed in the last row of table where the value under column A is "-35", indicating that A (-) is worse than A (+) by 35.
- From the AB interaction, the best results occur when B (+), which is also confirmed by the last row under B (-87)
- In the BD interaction, the best results appear to be B (-) and D (+), yet the D (+) slope is much less steep than the D (-) slope. In such cases, the lower slope i.e. D (+) should be chosen.

19) Capping Run

Using the factors derived from the ANOVA table i.e. A(+), B(+), C(+) and D(+) run a test to monitor the results.

3.4.6 B Vs C

3.4.6 a) In the B Vs C analysis the symbols B and C stands for two levels, (+) and (-) of a variable, or two processes or a pair of alternate method that need to be compared.

3.4.6 b) C is generally the current © process and B is supposedly a better (B) processes but they could be also two new processes.

3.4.6 c) B Vs C is a non-parametric comparative experimentation, where no assumption of normality is necessary for either the B or the C process distribution.

3.4.6 d) The term non-parametric is a third form of data observation. In variable data, there is measurement such as dimension, where there can be a continuous scale of a vast number of different readings in the attribute data, there is only 'good' or 'bad' 'pass' or 'fail'.

3.4.6 e) In non-parametric data, there are no measurements as in variables but only ranking of units from the best to worst.

3.4.6 f) The power of non-parametric ranking is that it takes only a

comparison between extremely small sample size from the two processes. ... often three from B process and three from C processes, to ensure with a high degree of confidence, that one is better than the other.

3.4.6 g) The pre-requisites of B Vs C.

- Final validation of previous techniques that had isolated the Xs
- Two processes to be validated
- Two sets of units, a good and bad to be validated (pair's comparison).

3.4.6 h) Significant of End-count

- No overlap end count

- 1) There are twenty ways which three Bs and three Cs can be ranked in order of these there is only one way out of twenty in which the three Bs come out on top and the three Cs are at the bottom.
- 2) When that happens, the hypothesis of no difference is rejected. Such a rejection is the objective of B Vs C test.
- 3) There is only one in twenty or 5%, risk that 3 Bs come out on top and 3 C's are at the bottom, it is through chance alone.
- 4) Concluding that B is better than C represents a one in twenty or 5%, chance or risks. This is known as the alpha risk.

3.4.6 g) This formula can be use also

No. of combination M is

$$M = \frac{(nB + nC)!}{(nB)! \times (nC)!}$$

Where nB = no.s of B samples
 nC = no.s of C samples
 ! = is a factorial

In the case of 3 B's and 3 C's
 the alpha risk is

$$\begin{aligned} & \frac{3! \times 3!}{(3 + 3)!} \\ &= \frac{(3 \times 2 \times 1) + (3 \times 2 \times 1)}{6 \times 5 \times 4 \times 3 \times 2 \times 1} \\ &= \frac{1}{5 \times 4} \\ &= \frac{1}{20} \\ &= 0.05 \text{ or } 5\% \end{aligned}$$

The alpha risk then is (1/M)

$$\text{thus } 1/M = \frac{(n[B])! \times (n[C])!}{(nB + nC)!}$$

3.4.7 Scatter Plots

- 3.4.7 a) After identifying the factors that is causing the variation in response (output) the RED X, PINK X team should also know how the factor level variation is affecting the response.
- 3.4.7 b) Knowing the relationship between the factor level and the output will help to establish a realistic tolerance.
- 3.4.7 c) If there is no relationship between the output and the factor is level, then the factor is not important and it's value and tolerance can be placed at much less conservative levels that are the most economical.
- 3.4.7 d) From the above, the output variation observed factor level will be the same at all level. Changing factor's level will only bring about a change in the average value and does not significantly affect the capability of the output.
- 3.4.7 e) For this type of correlationship, we would only apply tolerance control which is usually the least economical control method.
- 3.4.7 f) From the relationship curve below, it indicate a non-linear relationship curve. Discovering non-linear relationship is like finding a pot of gold at the end of the rainbow.

3.4.7 g) The non-linear relationship provide an opportunity to reduce output variation simply by choosing the correct level to run.

3.4.7 h) The most benefit is generally gained by selecting the factors level to coincide with the position on the curve where the slope is least, or visually where the curve is flat.

3.4.7. i) Procedure for determining the Realistic Tolerances

- 1) Select the output to be met. Practically RED X and PINK X etc. will have been pinpoint using earlier DOE methods.
- 2) Select a range of values for the RED X factor that is likely to fine-tune the output. Run at least 30 such values of the RED X and note the corresponding output values. Plot the results.
- 3) Draw a median line, called the line of regression through the thirty plots. Draw two parallel lines on each side of the median so as to contain all but one of the thirty points. Draw a vertical line through the center of the thirty points, to intercept the two external parallel lines.

The width (between the two external parallel lines and the vertical line) is known as the vertical scatter.

Vertical scatter is a measure of the total contribution to the output of all the variables added together, other than the particular factor X.

For factor X to be RED X, the vertical scatter must be the lowest value. If this intercept is large, the factor is a PINK X or even PALE PINK X rather than RED X.

- 4) If the output is a customer requirement, or there is a +/- specification (tolerance) limit, plot these points on the Y axis and draw two lines from their upper specification intersects the upper boundary of the scatter. Drop two lines from these intersection points perpendicular to the X-axis.
- 5) The horizontal intercept on the X-axis between these two lines determines the maximum tolerances permitted in order to ensure conformance to specifications. This would specify a minimum CD of I.O. Using the pre control rules, the horizontal intercept could be divided into four equal parts and only the middle half allowed as the preferred tolerance for the RED X. This would ensure a minimum cp of 20. Further, the larger value of the RED X variable should be at the center of the horizontal intercept.
- 6) These realistic target values and tolerances for the RED X should be compared against existing values and tolerances and the necessary changes made to ensure zero defects.

谢宁 (Shainin) DOE 工具培训课程大纲

多利安·谢宁 (Dorian Shainin) 的谢宁 (Shainin) DOE 工具作为一个系统解决问题的方法，具有计算简单、解决问题针对性强、成本低、效果好的优点。“没有戴明，美国就不会有质量哲学；没有朱兰，美国就不会有质量的方向；没有谢宁，美国就无从解决质量问题”。这句名言总结了美国最伟大的三位质量大师的贡献。

谢宁 (Shainin) DOE 工具一些原始案例主要是针对产品问题的，然而国内厂家更加关注工艺过程质量问题，所以本课程重点在谢宁 (Shainin) DOE 工具解决工艺过程质量问题方面的应用。

一. **培训目的：** 通过本课程的学习，使学员能掌握谢宁 (Shainin) DOE 工具解决工艺过程质量问题。

二. **培训对象：** 产品设计开发人员、工艺设计开发人员、质量人员、管理质量工程师和现场工程师。

三. 课程内容

● 谢宁 DOE 简介

过程改进与优化

系统解决问题的方法

制造过程的稳健设计

试验设计简介

● 过程多层变量图 Multi-Vari Chart

过程多层变差模型

分层法调查表

多层变量图

多层变量过程分析案例

- 过程的 B 与 C 比较 B vs .C

过程分析工具：排列图、因果图、KCC&KPC 矩阵

过程的 B 与 C 比较

G8D 变化比较法分过程

B 与 C 比较过程分析案例

- 过程的成对比较 Paired Comparisons

好的和坏的过程选取

因果图、KCC&KPC 矩阵

成对比较过程分析案例

- 过程的搜索 Process Search

工艺方案的确定

过程的搜索确定工艺方案

- 变量搜索技术 Variables Search

工艺参数的确定

过程的搜索确定工艺参数

- 6. 全因子实验 Full Factorials

- 7. 公差设计 Realistic Tolerance Parallelogram

过程工艺参数优化设计和目标值

同步工程

制造过程能力和测量过程能力分析

回归分析确定过程工艺参数上下公差

四. 课程学时：每天七小时，共三天

正交试验设计培训课程大纲

一. 培训目的：通过本课程的学习，使学员能掌握 DOE 工具, 进行产品、过程的健壮设计及持续改进。

二. 培训对象：产品设计开发人员、工艺设计开发人员、质量人员、管理质量工程师和现场工程师。

三. 课程内容

- 试验设计发展三个阶段
- 三次设计 结构设计 参数设计 容差设计
- 实验设计的目的
- 实验设计四种方法
 - 试误法
 - 一次一因子实验法
 - 全因子实验法
 - 田口式正交表实验法
- 田口式正交试验设计
 - 田口式正交表的优点
 - 正交表性质
 - 正交表分类
 - 无交互作用正交表
 - 无交互作用正交表
 - 混合水平正交表
- 正交试验设计的基本步骤
- DOE 案例

- 无交互作用正交表案例
- 无交互作用正交表案例
- 混合水平正交表案例

- DOE 方差分析及案例
- MINITAB 软件正交试验设计及案例
- 田口博士的 S/N 比
- 三种质量计量方法之比较
- 望目特性之 S/N 比及案例
- 望小特性之 S/N 比及案例
- 原点直线型之 S/N 比及案例
- 稳健质量设计的原理
- 质量损失函数之应用
- 因子效应的混淆及直交表实验的分辨率
- 实验误差及变差的分解

- MINITAB 软件
 - 实验分组 (Blocking)
 - 试验随机化 (Randomization)
 - 全因子设计
 - 部分因子设计
 - 筛选试验 Plackett - Burman Design
 - 概率图和 Pareto 图
 - 中心组合设计
 - Box-Behnken 试验设计

- 田口正交设计
- 混料试验设计
- DOE 方差分析

四. 课程学时: 每天七小时 , 共三天

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工作经历

从事职工成人教育两年

航天工业部研发工程师及分厂质量主管十二年

咨询公司咨询师和认证公司审核员九年

专业从事

汽车制造行业 TS16949 及其质量工具、六西格玛质量改进工具培训

培训的客户

重庆长安集团、延锋伟世通、NEC、德尔福、德纳、科世达华阳、麦格纳、
生益科技、奥托立夫、马勒发动机、曙光汽车集团、NEC、日立、韩泰轮
胎等。