Module 5

TAGUCHI METHOD

for

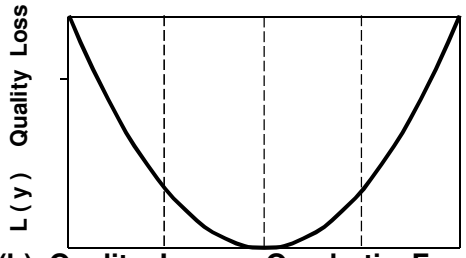
STATIC PROBLEMS

TAGUCHI'S CONCEPT of QUALITY-LOSS FUNCTION

- **Products meeting tolerance also inflict a quality loss**
- **Best quality when performance is on target**

Quality Loss Functions

(a) Quality Loss - Step Function



(b) Quality Loss - Quadratic Function

TAGUCHI'S QUADRATIC LOSS FUNCTION

- **Step Function**
  - **Quality Loss $L(y) = 0$ for $|y - m| \le \Delta_o$**
    $= \Delta_o$ otherwise
- **Quadratic Loss Function**
  - **Quality Loss $L(y) = k(y - m)^2$**
    where k is called the quality coefficient

INTERPRETATION of ENGINEERING TOLERANCES

- Step Quality Loss Function misrepresents quality from customer's point of view
- Quadratic Loss Function defined by Taguchi

$$L(y) = k(y - m)^2$$

AVERAGE QUALITY LOSS

- Quadratic quality loss function measures quality loss of a single unit with quality characteristic, say, 'y_1'

  ➔ Then Quality Loss, $L(y_1) = k(y_1 - m)^2$

- For 'n' units with $y_1, y_2, y_3, .., y_n$ the quality loss for each unit is

$$L(Y_1) = k(Y_1 - m)^2$$
$$L(Y_2) = k(Y_2 - m)^2$$
$$\cdots$$
$$L(Y_n) = k(Y_n - m)^2$$

AVERAGE QUALITY LOSS

- **The sum of all quality losses is**

$$L(Y_1) + L(Y_2) + \ldots + L(Y_n) = k[(Y_1 - m)^2 + \ldots + (Y_n - m)^2]$$

- **Average quality loss is**

$$Q_{av} = \frac{k}{n}[(Y_1 - m)^2 + \ldots + (Y_n - m)^2]$$

- **Finally**

$$Q_{av} = k[(\mu - m)^2 + \sigma^2]$$

MEASURE OF QUALITY

- **TOTAL LOSS TO SOCIETY DUE TO**
  - ***FUNCTIONAL VARIATIONS***
  - ***HARMFUL SIDE EFFECTS***

TAGUCHI'S QUADRATIC LOSS FUNCTION

REFRIGERATOR EXAMPLE

- **Assume k = 1 , target value m = -10 C**

$$Q = [(m - \mu)^2 + \sigma^2)]$$

- **Case 1 : mean μ = - 9.5 C , variance = .1**

Quality Loss = 0.35 (C)^2

- **Case 2 : mean μ = - 11 C , variance = .2**

Quality Loss = 1.2 (C)^2

INTERPRETATION OF AVERAGE QUALITY LOSS

- **$Q = k [(m - \mu)^2 + \sigma^2)]$**
- **Taguchi's quality loss function is a cost function, with MONEY element contained in ' k '**
- **' k ' occurs as multiplication factor or 'magnification factor ' of the statistical term $[(m - \mu)^2 + \sigma^2)]$**
- **Thus reducing $[(m - \mu)^2 + \sigma^2)]$ will reduce quality loss**

INTERPRETATION OF AVERAGE QUALITY LOSS

- ' k ' can be expressed as a product k1.k2.k3...kn
  - k1 ——> Purchasing efficiency
  - k2 ——> Servicing efficiency
  - k3 ——> Administration efficiency
  - k4 ——> Marketing & Sales efficiency
  - .
  - kn ——> Organisational efficiency
- Minimising ' k ' leads to about 7% to 10% reduction in quality loss
- Reducing $[(m - \mu)^2 + \sigma^2)]$ leads to more than 70% reduction in quality loss
- Reducing $[(m - \mu)^2 + \sigma^2)]$ also reduces ' k ' due to synergistic effects
- For Robust Design application we assume k = 1

REDUCING AVERAGE QUALITY LOSS

(a) by bringing mean on target

- $Q = k [(m - \mu)^2 + \sigma^2)]$
- Two terms are $(m - \mu)^2$ and σ^2
- $(m - \mu)^2$: Bring mean on target to reduce this term
- Conventional design concentrates on on bringing mean on target

REDUCING AVERAGE QUALITY LOSS

(b) by reducing variance

- σ^2 : Variance must be reduced . Conventional design reduces variance by screening or by tolerance design
- Robust design concentrates on reducing variance 'σ^2' without adding to the cost
- Finally, the mean 'μ' is put on target 'm'

ROBUST DESIGN METHODOLOGY

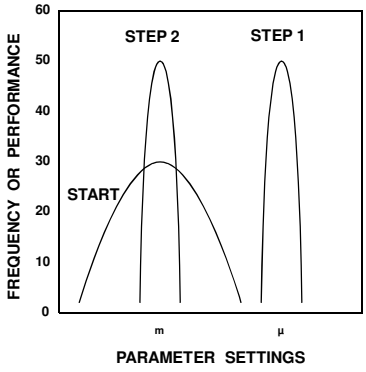
2 - STEP OPTIMIZATION

STEP 1 :

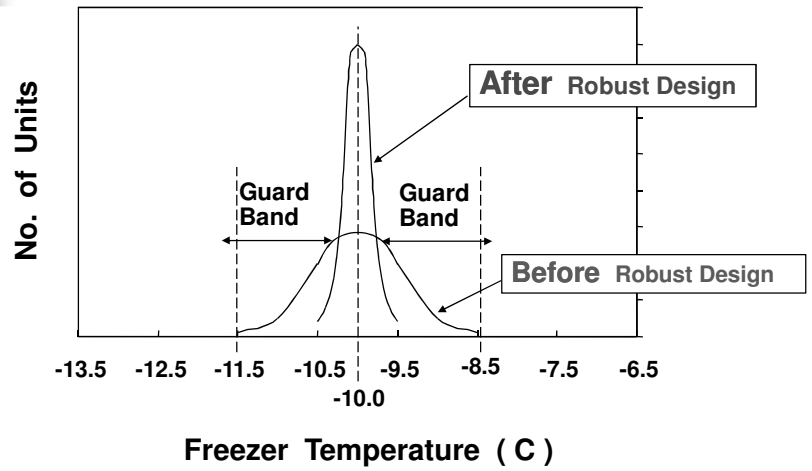
REDUCE VARIATION IRRESPECTIVE OF TARGET VALUE

STEP 2 :

ADJUST PERFORMANCE ON TARGET LEAVING VARIATION UNDISTURBED



Benefits of variance reduction



EXPLOITING NONLINEARITY

$Y = f(X, Z)$ where $X = (x_1, x_2, ..., x_n)$ noise factors

$Z = (z_1, z_2, ..., z_m)$ control factors

- If $\Delta x_1\ \Delta x_2 \cdots \Delta x_n$ are random deviations in the noise factors (X), then each one of these causes deviations in ' y '
- If Δ_y is the sum of all the deviations due to change in the noise factors, then

$$\Delta_y = \frac{\partial f}{\partial x_1}\Delta x_1 + \frac{\partial f}{\partial x_2}\Delta x_2 + \ldots + \frac{\partial f}{\partial x_n}\Delta x_n \quad .$$

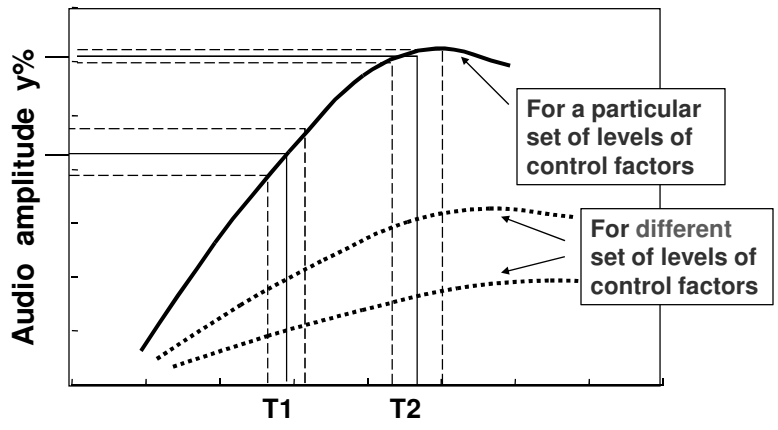
EXPLOITING NONLINEARITY

$$\Delta_y^2 = \left[\frac{\partial f}{\partial x_1}\right]^2 \Delta_{x_1}^2 + \left[\frac{\partial f}{\partial x_2}\right]^2 \Delta_{x_2}^2 + \cdots + \left[\frac{\partial f}{\partial x_n}\right]^2 \Delta_{x_n}^2$$

$$\sigma_y^2 = \left[\frac{\partial f}{\partial x_1}\right]^2 \sigma_{x_1}^2 + \left[\frac{\partial f}{\partial x_2}\right]^2 \sigma_{x_2}^2 + \cdots + \left[\frac{\partial f}{\partial x_n}\right]^2 \sigma_{x_n}^2$$

- **Terms are called SENSITIVITY COEFFICIENTS**
- **Robust design reduces sensitivity coefficients by adjusting levels of control factors (Z)**

Nonlinear Relationship Exploitation



EXAMPLES OF S / N RATIOS

(1) Smaller - the - Better type problems

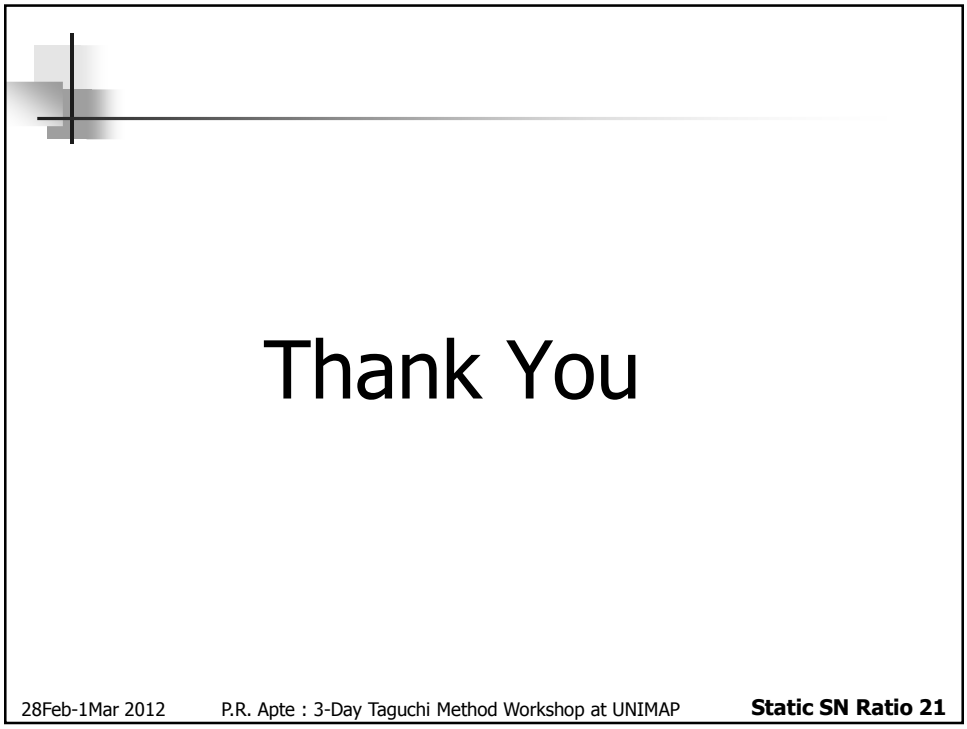
$$\eta = -10 \text{ Log}_{10}\left[\frac{1}{n}\sum (Y_1^2 + Y_2^2 + \ldots + Y_n^2)\right]$$

(2) Nominal - the - Best type problems

$$\eta = 10 \text{ Log}_{10}\left[\frac{\mu^2}{\sigma^2}\right] \quad .$$

CLASSIFICATION OF DESIGN PROBLEMS

- **Classification is based on type of SIGNAL factor**
- Static Problems : **(Signal Factor is Constant)**
  - **Smaller - the - Better**
  - **Nominal - the - Best**
  - **Larger - the - Better**
  - **Signed Target**
  - **Fraction Defective**
  - **Ordered Categorical**
  - **Curve or Vector Response**
- Dynamic Problems : **(Response follows Signal)**
  - **Continuous - Continuous (C-C)**
  - **Continuous - Digital (C-D)**
  - **Digital - Continuous (D-C)**
  - **Digital - Digital (D-D)**


Thank You
28Feb-1Mar 2012
P.R. Apte : 3-Day Taguchi Method Workshop at UNIMAP
Static SN Ratio 21