DEPARTMENT OF AEROSPACE ENGINEERING
19MEE304 Total Quality Management

Topic: Taguchi Quality Loss Function

1. Introduction to Taguchi's Quality Loss Function

📌 **Definition:**
The **Taguchi Quality Loss Function (QLF)** is a mathematical model that measures the **cost of deviating from the target value** in product and process design. Unlike traditional quality approaches that focus only on meeting specifications, **Taguchi emphasizes that even small deviations from the ideal target lead to a loss in quality**.

📌 **Key Concept:**

- Traditional quality control considers products **"good" or "bad"** based on tolerance limits.
- **Taguchi argues that any deviation from the target value results in a loss, even if within acceptable limits**.

📌 **Example:**
If the **ideal diameter of a bearing** is **10.00 mm**, both **9.98 mm and 10.02 mm** might be within tolerance, but they still cause **variation in performance**, leading to customer dissatisfaction.

2. Traditional View vs. Taguchi's View

Traditional Quality Approach (Tolerance-Based Thinking)

✅ Products are **acceptable** if they fall **within tolerance limits**.
✅ Products are **defective** if they are **outside tolerance limits**.
🚫 Ignores performance variations **within the limits**.
🚫 Sudden increase in defect rates **beyond tolerance limits**.

Taguchi's Approach (Loss-Based Thinking)

✅ **Quality is best at the target value** and degrades **gradually** as variation increases.
✅ Even **small deviations** cause losses (e.g., increased customer complaints, reduced

lifespan).
✅ **Loss increases exponentially** as deviation grows.

📌 **Illustration:**

- **Traditional View (Binary Thinking):** ✔ Good (within tolerance) ✖ Bad (outside tolerance)
- **Taguchi's View (Continuous Loss Function):** 📉 **Loss increases gradually** as variation increases.

3. Taguchi Loss Function Formula

The Taguchi Loss Function is given by:

$$L(x) = k(x - T)^2$$

Where:

- **L(x)** = Quality loss (cost) at a given value **x**.
- **k** = Loss coefficient (depends on industry and cost sensitivity).
- **x** = Actual value of the product characteristic.
- **T** = Target value of the characteristic.

📌 **Interpretation:**

- If **x = T** (product meets target exactly), **loss is zero**.
- If **x deviates from T**, **loss increases quadratically**.
- Larger deviations cause **exponential increases in loss**.

4. Types of Taguchi Loss Functions

Taguchi proposed **three types of loss functions** depending on the nature of the quality characteristic:

1️⃣ Nominal-the-Best (NTB) Loss Function

- Used when a **specific target value** is ideal (e.g., **shaft diameter, engine RPM**).
- Example: **Ideal resistance of an electrical component should be exactly 100Ω**.
- Loss increases as resistance deviates from 100Ω.

$$L(x) = k(x - T)^2$$

2️⃣ Smaller-the-Better (STB) Loss Function

- Used when **lower values are better** (e.g., **pollution levels, defects per unit, noise levels**).
- Example: **Lower fuel consumption is better (liters per km should be minimized).**

$$L(x) = kx^2$$

3️⃣ Larger-the-Better (LTB) Loss Function

- Used when **higher values are better** (e.g., **battery life, tensile strength, efficiency**).
- Example: **Higher tensile strength of materials is desirable.**

$$L(x) = k\left(\frac{1}{x^2}\right)$$

📌 **Graphical Representation:**
📈 Nominal-the-Best → **Parabolic loss curve centered at target value**.
📉 Smaller-the-Better → **Exponential increase in loss as value increases**.
📊 Larger-the-Better → **Exponential decrease in loss as value decreases**.

5. Industrial Applications of Taguchi Loss Function

🔹 Automotive Industry (Toyota Production System)

- **Application: Engine component tolerances** (pistons, crankshafts).
- **Goal:** Maintain **precision dimensions** to reduce fuel consumption and emissions.

🔹 Electronics Industry (Intel & Samsung)

- **Application: Microprocessor design and semiconductor manufacturing**.
- **Goal:** Reduce variation in **circuit resistance and power efficiency**.

🔹 Aerospace Industry (Boeing & Airbus)

- **Application: Turbine blade manufacturing** for jet engines.
- **Goal:** Ensure **precise aerodynamic shape** to reduce fuel burn and improve efficiency.

🔹 Healthcare Industry (Medical Devices - GE Healthcare, Medtronic)

- **Application: MRI machine noise levels and pacemaker battery life**.
- **Goal: Minimize deviations** from ideal power consumption to **extend battery life**.

6. Benefits of Using Taguchi Quality Loss Function

✅ **Minimizes variations & improves consistency**.
✅ **Reduces total cost** of quality (waste, rework, warranty claims).
✅ **Customer satisfaction increases** due to fewer defects.
✅ **Better process control and product design**.
✅ **Promotes robust engineering** by focusing on achieving target values.

7. Case Study: Taguchi Method in Semiconductor Manufacturing (Intel)

📌 **Problem:** Intel faced **high rejection rates in microprocessor chips** due to slight variations in circuit dimensions.

📌 **Solution:**
1️⃣ Used **Taguchi Loss Function** to determine the impact of **deviations in chip size** on performance.
2️⃣ Implemented **process control improvements** to reduce dimensional variations.
3️⃣ Focused on **designing robust chips** that function reliably even with minor fluctuations.

📌 **Outcome:**
✅ **Reduced chip failure rates by 25%**.
✅ **Increased production yield and cost savings**.
✅ **Enhanced overall processor performance and reliability**.

8. Limitations of Taguchi Quality Loss Function

🚫 May require **complex calculations** for determining loss coefficient **k**.
🚫 Some processes **do not follow quadratic loss trends**.
🚫 Requires **detailed historical data** for effective implementation.

9. Conclusion

🔷 **Taguchi's Quality Loss Function (QLF) is a powerful tool** that quantifies quality loss due to variation.

◈ Helps organizations **focus on minimizing deviations from the target**, not just meeting tolerance limits.

◈ **Widely used in industries** like automotive, aerospace, electronics, and healthcare.

◈ When applied correctly, **it reduces costs, improves reliability, and enhances customer satisfaction**.