Design an Inspection Strategy on DFT Checking to Determine the Quality Risk through the O.C. Curve on Single Sampling Plan using the Best Expert Decision under MCDM Environment.

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1. Abstract:
In industry, mainly in oil refinery & petrochemical sectors are looking over a problem for improper DFT(Dry Film Thickness) in large number of area (piping & tank maintained) painting system by third party. Result, consumer’s risk is gradually increased.

In this research venture, developed a procedure to draw an O.C. curve using Minitab software to minimize the consumer’s risk on external & internal in a large area of tank & pipe line painting to resist corrosion by best expert’s review using MCDM method.

The paper deals with large area coating system by measuring NDT methods (DFT) to improve the quality level as well as better inspection strategy.

Keywords: O.C. curve, DFT, single sampling plan, Consumer’s Risk, Lot Tolerance Percent defective(LTPD),Time study method, MCDM.

2. Introduction
• Acceptance sampling is an inspection procedure used to determine whether to accept or reject a specific quantity of material. It is a part of operation management or of accounting, auditing and services quality supervision. Acceptance sampling is most likely to be useful in the following situation:
  1) When the time and cost of 100% inspection is extremely high.
  2) When 100% inspection is not technologically feasible or would require.
  3) When there are many items or spots to be inspected and the inspection error rate is sufficiently higher than 100% inspection might cause a higher percentage of defectives (here, low DFT in painting inspection) to be passed than would occur with the use of sampling plan.
• Dry film thickness (DFT) is probably the single most important measurement made during inspection or quality control of protective coating application. Even the most basic protective coating specification will inevitably require the DFT to be measured. It is considered to be the most important factor determining the durability of a coating system. The thickness of each coating layer in a system and the total system DFT will have to be measured and recorded to show that the specified system will meet the desired durability.

In industry, Standards Used for DFT Measurement: SSPC-PA 2, AS 3894.3, ISO 19840, PSPC.

![Figure-1:Elcometer:DFT measurement machine](image)

Time study is a direct and continuous observation of a task, using a timekeeping device (e.g., decimal minute stopwatch, computer-assisted electronic stopwatch, and checking videotape camera) to record the time taken to accomplish a task[3] and it is often used when:
• there are repetitive work cycles of short to long duration,
• wide variety of dissimilar work is performed, or
• process control elements constitute a part of the cycle.
Multiple criteria decision making (MCDM) is the process of selecting the best alternative from a set of feasible alternatives considering multiple conflicting criteria. In precise terms criteria are considered to be 'strictly' conflicting if the increase in satisfaction of one results in a decrease in satisfaction of the other. An MCDM process always contains at least two alternatives and two conflicting criteria (Bhattacharya et al., 2003). MCDM are divided into two broad categories: Multiple Attribute Decision Making (MADM) and Multiple Objective Decision Making (MODM).

3. Statement of the problem
Basically, in oil refinery/petrochemical based industry required large number of area (tank and pipe line) to come under painting system to resists corrosion. This type of project done by third party. To maintain the quality control by DFT checking responsibilities are vested on the department of inspection. Practically, this is not possible to 100% inspection. An inspector inspected this type of jobs by his experience and applies Standards Used for DFT Measurement. Lack of 100% inspection, improper coating found many places, Result, gradually increase the risk to failure the coating system.

4. Research objectives
Standards Used for DFT Measurement i.e. SSPC-PA 2, AS 3894.3,ISO 19840,PSPC etc. are implemented to inspection on average 20-30 spots per 100 square meter area, but in this research venture we fixed the lot size in respect of 100 spots per square meters area and taken the sample size by various inspection engineers to draw an O.C curve and selecting the best expert to minimize the quality risk factor in painting inspection as follows:
1. To determine the consumer’s risk by draw the O.C. curve for spot sampling.
2. To compare the effect of strategic planning on successful implementation of painting inspection by various quality control engineers.
3. To establish the impact of other factors (i.e. inspection time, sample size, consumer’s risk etc.), for optimization of this job.
4. To determine the best expert by ranking MCDM method for optimizing as well as better inspection and reduce the company’s risk.

5. Research Design Framework

- Fixed the lot size and
- collected the various sample size of the DFT check in painting inspection.
- Draw the O.C curve to determine the consumer’ risk individually for various experts by Minitab software.
- Determine the other factors related with inspection methodology.
- Ranking the best expert to minimize the risk factors by MCDM method.
- Optimized the company’s risk factor with best expert’s review.
6. CASE STUDY AT I.O.C.L. LTD (HALDIA REFINERY)

Company Profile:
The Haldia Refinery for processing 2.5 MMTPA of Middle East crude was commissioned in January, 1975. With two sectors—one for producing fuel products and the other for lube base stocks.

7. Mathematical Model:

7.1. PART-1
Taken the 732 square meters area painting inspection, we, fixed the inspection spot in 100 spot/sq.meter and get a lot size 73200 units.

- Existing Sampling plan adapted by various experienced expert in IOCL to draw a O.C curve in this case study as given below:

<table>
<thead>
<tr>
<th>SL. NO.</th>
<th>LOT SIZE (N)</th>
<th>EXPERTS</th>
<th>SAMPLE SIZE (n)</th>
<th>ACCEPTANCE NUMBER (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73,200</td>
<td>A</td>
<td>1600</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>73,200</td>
<td>B</td>
<td>1200</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>73,200</td>
<td>C</td>
<td>2000</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>73,200</td>
<td>D</td>
<td>1000</td>
<td>10</td>
</tr>
</tbody>
</table>

Table-1:

- For calculation of probabilities of acceptance, a Poisson’s Distribution method is used as given below.
  - Drawing an O.C curve on existing sampling plan:
    Lot size (N) =73,200
    Sample size (n) =1600,1200,2000,1000 etc.by various experts.
  - Inspected the sample of lot size and if number of defectives (here, low DFT) are equal to Acceptance number (C) then accept the DFT or if it is more than C (i.e. =1, 2, 3…) then it will reject the lot.
  - We have to draw an O.C curve for this assume the
    Percent of defectives in a lot as, P’ (% defectives) =0.1%, 0.5%, 0.8%, 1.0%, 2.0%, 4.0%, 6.0%, 10.0%

7.1.1. According to Expert “A”
N=73200
n=1600
C=50
We consider, simplifying the calculation all data divided by 100 and we get
N=732
n=16
C=0

Table-2: Calculation of single sampling plan for Expert-A

- Existing Sampling plan adapted by various experienced expert in IOCL to draw a O.C curve in this case study as given below:

<table>
<thead>
<tr>
<th>SL. NO.</th>
<th>Percent of defectives (P’)</th>
<th>np’</th>
<th>Probability of Acceptance (Pₐ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1%</td>
<td>0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>2</td>
<td>0.5%</td>
<td>0.08</td>
<td>0.92</td>
</tr>
<tr>
<td>3</td>
<td>0.8%</td>
<td>0.12</td>
<td>0.88</td>
</tr>
<tr>
<td>4</td>
<td>1.0%</td>
<td>0.16</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>2.0%</td>
<td>0.32</td>
<td>0.72</td>
</tr>
<tr>
<td>6</td>
<td>4.0%</td>
<td>0.64</td>
<td>0.52</td>
</tr>
<tr>
<td>7</td>
<td>6.0%</td>
<td>0.96</td>
<td>0.38</td>
</tr>
<tr>
<td>8</td>
<td>10.0%</td>
<td>1.60</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Figure-5: O.C. curve for Expert-A
If we consider lot tolerance percent defectives as 5% corresponding consumer’s risk can be calculated.

From fig-1, if we consider LTPD= 5%. The Consumers risk is 44.9%.

Hence consumer’s risk is 44.9% with the existing sampling plan. It must be minimized.

Similarly, 7.1.2. According to Expert -B

<table>
<thead>
<tr>
<th>SL NO.</th>
<th>P’</th>
<th>np’</th>
<th>Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1%</td>
<td>0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>0.5%</td>
<td>0.06</td>
<td>0.94</td>
</tr>
<tr>
<td>3</td>
<td>0.8%</td>
<td>0.10</td>
<td>0.91</td>
</tr>
<tr>
<td>4</td>
<td>1.0%</td>
<td>0.12</td>
<td>0.89</td>
</tr>
<tr>
<td>5</td>
<td>2.0%</td>
<td>0.24</td>
<td>0.77</td>
</tr>
<tr>
<td>6</td>
<td>4.0%</td>
<td>0.48</td>
<td>0.61</td>
</tr>
<tr>
<td>7</td>
<td>6.0%</td>
<td>0.72</td>
<td>0.48</td>
</tr>
<tr>
<td>8</td>
<td>10.0%</td>
<td>1.20</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Table-3: Calculation of single sampling plan for Expert-B

From fig if we consider LTPD= 5%. Consumers risk is 44.9%.

Hence consumer’s risk is 44.9% with the existing sampling plan. It must be minimized.

7.1.3. According to Expert -C

<table>
<thead>
<tr>
<th>SL NO.</th>
<th>P’</th>
<th>np’</th>
<th>Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1%</td>
<td>0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>2</td>
<td>0.5%</td>
<td>0.10</td>
<td>0.90</td>
</tr>
<tr>
<td>3</td>
<td>0.8%</td>
<td>0.16</td>
<td>0.85</td>
</tr>
<tr>
<td>4</td>
<td>1.0%</td>
<td>0.20</td>
<td>0.82</td>
</tr>
<tr>
<td>5</td>
<td>2.0%</td>
<td>0.40</td>
<td>0.67</td>
</tr>
<tr>
<td>6</td>
<td>4.0%</td>
<td>0.80</td>
<td>0.45</td>
</tr>
<tr>
<td>7</td>
<td>6.0%</td>
<td>1.20</td>
<td>0.30</td>
</tr>
<tr>
<td>8</td>
<td>10.0%</td>
<td>2.00</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Table-4: Calculation of single sampling plan for Expert-C

From fig if we consider LTPD= 5%. Consumers risk is 36.8%.

Hence consumer’s risk is 36.8% with the existing sampling plan. It must be minimized.

7.1.4. According to Expert “D”

<table>
<thead>
<tr>
<th>SL NO.</th>
<th>P’</th>
<th>np’</th>
<th>Pa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1%</td>
<td>0.01</td>
<td>0.99</td>
</tr>
<tr>
<td>2</td>
<td>0.5%</td>
<td>0.05</td>
<td>0.93</td>
</tr>
<tr>
<td>3</td>
<td>0.8%</td>
<td>0.08</td>
<td>0.92</td>
</tr>
<tr>
<td>4</td>
<td>1.0%</td>
<td>0.10</td>
<td>0.90</td>
</tr>
<tr>
<td>5</td>
<td>2.0%</td>
<td>0.20</td>
<td>0.81</td>
</tr>
<tr>
<td>6</td>
<td>4.0%</td>
<td>0.40</td>
<td>0.67</td>
</tr>
<tr>
<td>7</td>
<td>6.0%</td>
<td>1.60</td>
<td>0.55</td>
</tr>
<tr>
<td>8</td>
<td>10.0%</td>
<td>1.00</td>
<td>0.368</td>
</tr>
</tbody>
</table>

Table-5: Calculation of single sampling plan for Expert-D

From fig if we consider LTPD= 5%. Consumers risk is 54.9%.

Hence consumer’s risk is 54.9% with the existing sampling plan. It must be minimized.
From fig if we consider LTPD= 5%. Consumers risk is 60.7%
Hence consumer’s risk is 60.7% with the existing sampling plan. It must be minimized.

7.2. Limitations and problems in existing sampling plan:
1. Lot tolerance percent defective are larger.
2. As this sampling plan is based upon single sampling, there may be possibility of acceptance of defective lots.
3. As acceptance number C=0, vendors may be supply by considering this acceptance number. However some tolerance limit should be given to the vendors for better coordination and commitment.
4. Consumer’s risk in a single sampling plan is always larger and it is acceptance of such a lot, which would have been rejected. It can affect the consumer and his next production work and assembly work.

7.3. Possible Remedies for Overcoming the Limitations:
1. If increases the sample size and increases the acceptance number lot tolerance % defective can be minimized. But still it is single sampling hence there may be possibility of acceptance of defective components.
2. By using single sampling inspection of various experts, comparatively analysis to determine the best minimized LTPD of this expert’s decision.
3. Using the another optimization method MCDM to calculate the ranking the best expert in respect of sample size, consumer risk, and working time to minimized as well as optimized the inspection system.

7.4. PART-2
7.4.1. Simple additive weighting (SAW)
Step 1 Formation of decision matrix: Criterion outcomes of decision alternatives can be collected in a table called Decision Matrix comprised of a set of columns and rows. The matrix rows represent decision alternatives, with matrix columns representing criteria. A value found at the intersection of row and column in the matrix represents a criterion outcome - a measured or predicted performance of a decision alternative on a criterion. The decision matrix is a central structure of the MCDA/MCDM since it contains the data for comparison of decision alternatives.

\[ \begin{bmatrix}
A_1 & x_{i1} & \cdots & x_{ij} & \cdots & x_{in} \\
\vdots & \vdots & \ddots & \vdots & \cdots & \vdots \\
A_m & x_{ml} & \cdots & x_{mj} & \cdots & x_{mn}
\end{bmatrix} \]

\[ X = A_j x_{i1} \cdots x_{ij} \cdots x_{in} \]

\[ \cdots \cdots (1) \]

\[ x_{ij} \] is the performance rating of alternative i with respect to criterion j.
\[ A_j \] is ith alternative, \[ C_j \] is the jth criterion

Step 2 Formation of Weight Matrix:
Different importance weights to various criteria may be awarded by the decision makers. These importance weights forms the weight as follows.

\[ W = [W_1 \cdots W_j \cdots W_n] \]

\[ \cdots \cdots (2) \]

Step 3 Normalization of performance rating
Units and dimensions of performance ratings of columns under criteria differ. For the purpose of comparison, these performance ratings are converted into dimensionless units by normalization using following equations:

\[ \bar{x}_{ij} = \frac{x_{ij}}{\max_i(x_{ij})} \]

for benefit criteria

\[ \cdots \cdots (3) \]
\[
\bar{x}_{ij} = \frac{\min_i (x_{ij})}{x_{ij}} \quad \text{for non-benefit criteria} \ldots (4)
\]

Normalized decision matrix

**Step 4: Composite decision score:**

\[
\bar{X} = \left[ \bar{x}_{11} \ldots \bar{x}_{1j} \ldots \bar{x}_{1n} \right] \\
A_1 \bar{x}_{11} \ldots \bar{x}_{1j} \ldots \bar{x}_{1n} \\
A_2 \bar{x}_{11} \ldots \bar{x}_{1j} \ldots \bar{x}_{1n} \\
A_m \bar{x}_{11} \ldots \bar{x}_{1j} \ldots \bar{x}_{1n}
\]

\[
\bar{X} = \begin{bmatrix}
\bar{x}_{11} & \cdots & \bar{x}_{1j} & \cdots & \bar{x}_{1n} \\
\bar{x}_{21} & \cdots & \bar{x}_{2j} & \cdots & \bar{x}_{2n} \\
\vdots & \ddots & \vdots & \ddots & \vdots \\
\bar{x}_{m1} & \cdots & \bar{x}_{mj} & \cdots & \bar{x}_{mn}
\end{bmatrix}_{m \times n}
\]

Computation of composite score (C_{Si}) for alternatives.

\[
C_{Si} = \sum_{j=1}^{n} (w_j \times \bar{x}_{ij})
\]

**Step 5: Ranking and selection of best alternative:**

Ranking of products in descending order of composite scores (C_{Si})

---

**Table 6 - Formation of Matrix comparing with other Inspection Factors:**

<table>
<thead>
<tr>
<th>SL. NO.</th>
<th>SAMPLE SIZE(n)</th>
<th>CONSUMER RISK (L.T.P.D) [5%]</th>
<th>TIME (TIME STUDY METHOD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPART-A</td>
<td>16</td>
<td>44.9%</td>
<td>7min.</td>
</tr>
<tr>
<td>EXPART-B</td>
<td>12</td>
<td>54.9%</td>
<td>5.4min.</td>
</tr>
<tr>
<td>EXPART-C</td>
<td>20</td>
<td>36.8%</td>
<td>9min.</td>
</tr>
<tr>
<td>EXPERT-D</td>
<td>10</td>
<td>60.7%</td>
<td>4.5min.</td>
</tr>
</tbody>
</table>

**Table 7 - Weighted values by Entropy method:**

<table>
<thead>
<tr>
<th>Criteria-1</th>
<th>Criteria-2</th>
<th>Criteria-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3381</td>
<td>0.3222</td>
<td>0.3397</td>
</tr>
</tbody>
</table>

**Table 8 - Final result in ranking:**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7529</td>
<td>0.7019</td>
<td>0.8301</td>
<td>0.7041</td>
</tr>
</tbody>
</table>

Arranging the final value in descending order:

E3 > E1 > E4 > E2

---

**Result of the SAW method:**

**Figure 9: Ranking best Expert by MCDM.**
8. Conclusions:
The design of acceptance sampling process of this particular job includes decisions about sampling versus complete inspection. In this design strategy has shown prominently the quality risk through the graphs individually for each inspection experts, using Minitab software, that can easily and more quickly calculate and draw operating characteristic curve.
The second level optimization tool, MCDM is used for selection the best expert comparing with other factors using Matlab software that can easily shown the graph for best decision through expert’s ranking.
This model helps the large number of painting inspection become automated as well as less time consuming.

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References: