The Implementation of Maintenance Quality Function Deployment (MQFD) to Improve the Quality Maintenance Management for the Upstream Oil and Gas Industry

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Abstract. The global energy market is still dominated by oil and gas energy. Pipeline is one of the most efficient means of distributing crude oil. In an oil and gas production unit, pipes are a means that often fail. A pipeline will operate optimally if it gets good maintenance. The concept of Total Productive Maintenance (TPM) is an implementation subject that includes the concept of quality improvement engineering, or commonly known as TQM), but in its application, TPM eliminates one of the strategies in TQM, which reflects the voice of the operator (user’s voice) to influence quality improvement ongoing maintenance, so as to perfect the TPM approach, a supporting technique is needed that can reflect the operator's voice, namely QFD, so that the combination of the two methods or so-called Maintenance Quality Function Deployment (MQFD) models is considered to be able to improve the quality of maintenance because it is a more comprehensive approach, and involves all elements involved, so that the expected quality improvement can be in accordance with the rules of total quality management. Based on the results of the TPM parameter calculation, it is known that all OEE values have met the world’s standard of 86%, in carrying out its operations there are still reports of damage, leakage, and vandalism in the production pipeline. Based on the results of the identification of user’s voice, there are 19 attributes of maintenance quality that must be prioritized.

Keywords: Maintenance management, maintenance strategy, upstream oil and gas industry, Maintenance Quality Function Deployment (MQFD), maintenance parameters of TPM, Quality Function Deployment (QFD).

1. Introduction
At the industrial development 4.0 stage, there is an increase in the complexity of facilities, equipment, systems, problems, and costs involved in maintenance operations. Until now, the global energy market is still dominated by oil and gas energy sources, and this condition is expected to remain until 2030 [1]. A pipeline is one of the most efficient means of channeling crude oil. In an oil and gas production unit, a pipe is a means that often fail, this is because the pipe is the largest element in the production unit so that the chance of failure tends to be greater than other elements [2]. One of the causes of failure in the production pipe in the form of leaking or rupture is the thinning or degradation of the pipe due to corrosion in a long time.
Based on observations on the HazOb data, it was found several reports related to unsafe conditions, including caused by equipment damage, pipe leaks, layout errors, etc. This can result in disruption of productivity, safety, and environment, so an effort is needed to improve the quality of maintenance of facilities in the field to prevent damage to the production pipe installation, while still paying attention to quality and safety.

The approach that can be applied as an effort to improve maintenance management is the concept of Total Productive Maintenance (TPM). TPM itself is a subject of implementation and research that includes the concept of quality improvement engineering, or commonly known as TQM [3]. But in its application, TPM eliminates one of the strategies that exist in TQM, namely reflecting the user’s voice to influence the improvement of the quality of ongoing maintenance. To perfect the TPM approach, a supporting technique is needed that can reflect the voice of the operator, the technique is known as the Quality Function Deployment (QFD) [4]. By combining TPM and QFD as a new approach that is expected to be more optimal in improving the quality of maintenance, it can also be more comprehensive in accommodating user’s voices than existing maintenance methods [5]. Pramod et al, 2006 called this new model the term Maintenance Quality Function Deployment (MQFD).

2. Research Methodology

This research methodology is a process or steps is taken to get the data to be used in this research.

2.1 Data Needs

The MQFD model requires two supporting data, namely the TPM supporting parameters and the user’s voice questionnaire. TPM supporting parameter data includes crude oil production data, and historical pipe maintenance data. Meanwhile, the QFD questionnaire variables are attributes of technical needs that are in accordance with ASME B31.8S:2016 regulations [6].

2.2 Data Processing Techniques

Data processing will be carried out in accordance with predetermined methods. In this study, data processing consists of two stages, namely TPM method data processing and QFD method data processing, as follows.

1. Total Productive Maintenance (TPM)

The following calculations are needed in processing TPM data [7]

   a. Calculation of Mean Down Time (MDT)

   \[
   MDT = \frac{Total \ Downtime}{Frequensi \ Downtime} \tag{1}
   \]

   b. Calculation of Mean Time Between Failures (MTBF)

   \[
   MTBF = \frac{Time \ Between \ Failure}{Number \ of \ Failure} \tag{2}
   \]

   c. Calculation of Mean Time to Repair (MTTR)

   \[
   MTTR = \frac{Total \ Repair \ Time}{Number \ of \ Repair} \tag{3}
   \]

   d. Calculation of Overall Equipment Efficiency (OEE)

   \[
   OEE = Availability \ (A) \times \ Performance \ Efficiency \ (P) \times \ Rate \ of \ Quality \ (Q) \tag{4}
   \]

   With:

   \[
   A = \frac{Schedule \ Running \ time-Downtime}{Schedule \ Running \ time} \times 100\% \tag{5}
   \]

   \[
   P = \frac{Processed \ Amount}{Operating \ Time/ \ Cycle \ Time} \times 100\% \tag{6}
   \]

   \[
   Q = \frac{Process \ Amount - \ Defect \ Amount}{Process \ Amount} \times 100\% \tag{7}
   \]
2. Quality Function Deployment (QFD)

Following are the stages in QFD method data processing:

a. Calculation of Interest Level Questionnaire Results

\[
\text{Total Nilai} = (N_1 \times 1) + (N_2 \times 2) + (N_3 \times 3) + (N_4 \times 4) + (N_5 \times 5)
\]  

b. Calculation of Satisfaction Level Questionnaire Results

\[
\text{Total Value} = (N_1 \times 5) + (N_2 \times 4) + (N_3 \times 3) + (N_4 \times 2) + (N_5 \times 1)
\]

Where:
- \(N_1\) = Number of respondents with "not important" or "not good" answers
- \(N_2\) = Number of respondents with "less important" or "less good" answers
- \(N_3\) = Number of respondents with "quite important" or "quite good" answers
- \(N_4\) = Number of respondents with "important" or "good" answers
- \(N_5\) = Number of respondents with "very important" or "very good" answers

c. Calculation of Gap Level Questionnaire Results

\[
\text{Gap Level} = (\text{Satisfaction Level}) - (\text{Interest Level})
\]

d. Determine Correlation Values

There are 3 types of correlations, with weight provisions as follows:
- \(\Theta\) = strong correlation (weight value of 9)
- \(O\) = Medium correlation (weight value 3)
- \(\Delta\) = Weak correlation (weighted value 1)

e. Calculation of CTI Relative Correlation Weight

\[
\text{CTI Relative Weight} = \frac{\text{CTI Value}}{\sum \text{CTI Value}} \times 100\%
\]

f. Calculation of Relative Correlation Weight of Technical Languages

\[
\text{Tech Languages} = \frac{\text{Technical Correlation Value}}{\sum \text{Technical Correlation Value}} \times 100\%
\]

g. Calculation of total Normalization Value

\[
\text{Normalization} = \text{CTI Relative Weight} + \text{Relative Weight of Tech Languages}
\]

3. Result and Discussion

The MQFD model has 2 main discussions, namely TPM and QFD. The initial discussion of this model is the TPM parameter values that are used as a reference for evaluating performance or successful implementation of a pipeline maintenance activities in the field [10], as well as the company's overall success in implementing Total Productive Maintenance (TPM).

| TAG NUMBER   | Year | Month | MDT | MTBF | MTTR | OEE  |
|--------------|------|-------|-----|------|------|------|
| PL-B-003-2"  | 2019 |       |     |      |      |      |
|              |      | June  | 71  | 649  | 71   | 86%  |
|              |      | July  | 0   | 0    | 0    | 95%  |
|              |      | August| 0   | 0    | 0    | 86%  |
|              |      | September| 0  | 0    | 0    | 86%  |
|              |      | October| 15 | 729  | 15   | 86%  |
|              |      | November| 7  | 713  | 7    | 86%  |
|              |      | December| 0  | 0    | 0    | 86%  |
|              |      | January| 10 | 734  | 10   | 86%  |
|              |      | February| 0  | 0    | 0    | 86%  |
|              |      | March  | 0   | 0    | 0    | 86%  |
|              |      | April  | 0   | 0    | 0    | 86%  |
|              | 2020 |       |     |      |      |      |

Based on the data presented in Table 1 above, it is found that pipe have OEE values that meet world standards (85%) [8], but other supporting components for pipe maintenance still need to be improved, this is related to reports of leaks, pipe damage, and vandalism in the field. By following the MQFD model, this TPM method is refined with the QFD approach to reflect user’s voice to improve the
quality of pipe maintenance in the field. This pipe quality attribute is obtained based on pipe quality indicators that are by following the provisions of ASME B31.8 of 2016 which are used to compile a user information matrix and questionnaire data [9]. The data of the results of the user’s voice questionnaire are processed based on the calculation of the level of importance and level of satisfaction, as a basis for user information matrix in the preparation of the House of Quality (HOQ). Calculation of the level of a gap between the assessment of perception (level of satisfaction) with expectations (level of importance) is carried out as a material consideration in the priority of efforts to improve the quality of flowline maintenance in the field. To find out the most important priorities for flowline maintenance, 5 priority attributes for maintenance are chosen, as follows:

1. Priority 1  ➢ Pipe inspection report
2. Priority 2  ➢ OD/ID corrosion monitoring
3. Priority 3  ➢ Leak condition/failure history
4. Priority 4  ➢ Operator standards/specifications
   ➢ O&M Procedure
5. Priority 5  ➢ Suitability and condition of layer type
   ➢ Flow rate conditions

The next stage is making technical information matrix is a technical response, which is formulating an action plan that will be carried out to improve the quality of flowline maintenance. The technical language in this study was also formulated based on the quality attributes of pipe maintenance and adapted to the eight pillars of the TPM. Based on these two things, the following is a list of technical languages that have been formulated:

1. Establish and implement standard pipe design and operation policies
   By developing developments related to standard operating procedures by following the operating conditions, design specifications, standards or, regulations that apply to ensure the process of start-up, operation, and shutdown of equipment is carried out. Operate production facility equipment within safe operating limits, by following the standard operating procedures.
2. Carry out Technical Analysis (TA)
   By carrying out a system monitoring program in the form of checks related to the suitability of pressure, temperature, work cycle, etc. Prioritized systems for checking are systems for the main components, such as storage tanks, valves, manifolds, pumps, etc. Technical analysis is carried out when the component is damaged or when determining the replacement of new components when overhauling.
3. Carry out daily inspection
   Always carry out daily checks in the form of checking for pipe leaks, loose bolts, condition of components visually visible, etc. In carrying out daily checks, if there are components that need repairs, then backlog management can be scheduled repairs by adjusting at the level of damage.
4. Conducting pipeline reliability sample checks
   Examination of pipe reliability samples is done by sending samples of pipe pieces taken 100 hours before the implementation of preventive maintenance to the laboratory. The inspection of this sample aims to detect if there is a mismatch of damage to the pipe, such as due to an error in the coating.
5. Conduct pipe coating checks
   Always carry out checks on the pipe coating, this is done to anticipate the occurrence of pipe leaks, and as an effort to prevent corrosion.
6. Carry out operational tests
   Before the operation of the production system, it’s better if everyday testing of operational components, such as pressure and temperature check, pipe and supporting element conditions.
7. Compile and carry out regular operator training programs
   Schedule operator/employee training every 6 months. Increase personnel expertise in carrying out pipeline maintenance by providing regular training schedules and facilities. This aims to improve the operator's ability regarding how to maintain pipes.
8. Carry out Planned Component Replacement (PCR)
   The PCR program is carried out when the component life has reached half of the tool life. The replacement of these supporting components is intended as an effort so that the main components can achieve one tool life cycle before the overhaul.

9. Carry out a Preventive Maintenance Program (PM)
   The implementation of PM is a comprehensive preventive effort that regularly evaluates the main elements of the production system, such as pipelines as a means of transporting crude oil to detect potential problems and immediately design a schedule of maintenance tasks that will prevent the deterioration of operating conditions. The pipeline, restoration of cathodic protection, and scheduled repairs in the backlog.

10. Designing documentation procedures and integrated management information systems
    Conduct development related to standard documentation procedures and management information systems related to reporting events in the field. The design of the documentation procedure is carried out to facilitate the supervisor in carrying out event analysis. If the system is integrated, the symptom of the problem can also be evaluated through historical databases, so errors or mismatches can be resolved faster.

11. Developing SOPs related to work safety
    Developing operational standard procedures (SOP) related to work safety is an effort to achieve the goal of “zero defect, zero reject, zero accident”. This can be done by designing an instrumentation and control system for safety, always check the proper use of the operator's PPE, conducting a process hazard analysis.

12. Establish and implement standard policies in management and methods
    Developing policies related to standard management of operations and methods, such as designing instrumentation systems for operational and inspection methods.

The first step in preparing HOQ is to enter user information on the left side of the HOQ and the results of the calculation of the level of user satisfaction on the right side of the HOQ. Then, technical language or technical information is entered on the top side of HOQ. Table 2 shows the quality attributes of pipe maintenance as well as the user's voice for the questionnaire design in QFD. Meanwhile, Table 3 shows the technical requirements.

| Category      | CODE | DESCRIPTRION                     | Category      | CODE | DESCRIPTRION                     |
|---------------|------|----------------------------------|---------------|------|----------------------------------|
| Attribute data|      |                                  | Inspection    |      |                                  |
| AD-1          | Pipe wall thickness              | INSP-1        | Pressure tests|
| AD-2          | Diameter                         | INSP-2        | In-line inspections|
| AD-3          | Seam type and joint factor       | INSP-3        | Geometry tool inspections|
| AD-4          | Manufacturer                     | INSP-4        | Bell hole inspections|
| AD-5          | Material properties              | INSP-5        | CP inspections (CIS)|
| AD-6          | Equipment properties             | INSP-6        | Coating condition inspections|
| CON-1         | Bending method                   | TDS-1         | Process and instrumentation drawings|
| CON-2         | Joining method, process, inspection results | TDS-2 | Pipeline alignment drawings|
| CON-3         | Depth of cover                   | TDS-3         | Original construction inspector notes|
| CON-4         | Crossings/casings               | TDS-4         | Pipeline aerial photography|
| CON-5         | Pressure test                    | TDS-5         | Facility drawings/maps|
| CON-6         | Field coating methods            | TDS-6         | As-built drawings|
| CON-7         | Inspection reports               | TDS-7         | Material certifications|
| CON-8         | Cathodic protection (CP) installed | TDS-8 | Survey reports/drawings|
| CON-9         | Coating type                     | TDS-9         | Safety-related condition reports|
| OPR-1         | Gas quality                      | TDS-10        | Operator standards/specifications|
| OPR-2         | Flow rate                        | TDS-11        | Industry standards/specifications|
| OPR-3         | Normal max and min operating     | TDS-12        | O&M procedures|
| OPR-4         | Pressures                        | TDS-13        | Emergency response plans|
| OPR-5         | Leak/failure history             | TDS-14        | Inspection records|
| OPR-6         | Coating condition                | TDS-15        | Test reports/records|
| OPR-7         | CP system performance            | TDS-16        | Incident reports|

Table 2 User’s Voice Attribute
Table 3 Technical Requirements

| CODE | DESCRIPTION |
|------|-------------|
| PDOP | Establish and implement standard pipe design and operation policies |
| TA   | Carry out Technical Analysis (TA) |
| DI   | Carry out daily inspection |
| RSC  | Conducting pipeline reliability sample checks |
| PCC  | Conduct pipe coating checks |
| OPT  | Carry out operational tests |
| ROTP | Compile and carry out regular operator training programs |
| PCR  | Carry out Planned Component Replacement (PCR) |
| PM   | Carry out a Preventive Maintenance Program (PM) |
| IMIS | Designing documentation procedures and integrated management information systems |
| SOPS | Developing SOPs related to work safety |
| SPOM | Establish and implement standard policies in management and methods |

Table 4 Total Normalization Value

| No | Technical Requirements Code | CTI | CTI Relative Value (%) | Technical Correlation | Tech. Correlation Relative Value (%) | Total Normalization |
|----|----------------------------|-----|------------------------|-----------------------|--------------------------------------|---------------------|
| 1  | PDOP                       | 3343| 10%                    | 65                    | 18%                                  | 28%                 |
| 2  | TA                         | 6463| 20%                    | 64                    | 18%                                  | 38%                 |
| 3  | DI                         | 6090| 18%                    | 45                    | 13%                                  | 31%                 |
| 4  | RSC                        | 1836| 6%                     | 40                    | 11%                                  | 17%                 |
| 5  | PCC                        | 1581| 5%                     | 45                    | 13%                                  | 17%                 |
| 6  | OPT                        | 3469| 11%                    | 26                    | 7%                                   | 18%                 |
| 7  | ROTP                       | 882 | 3%                     | 21                    | 6%                                   | 9%                  |
| 8  | PCR                        | 225 | 1%                     | 20                    | 6%                                   | 6%                  |
| 9  | PM                         | 817 | 2%                     | 11                    | 3%                                   | 6%                  |
| 10 | IMIS                       | 3401| 10%                    | 10                    | 3%                                   | 13%                 |
| 11 | SOPS                       | 801 | 2%                     | 9                     | 3%                                   | 5%                  |
| 12 | SPOM                       | 4060| 12%                    | 0                     | 0%                                   | 12%                 |
| Total |                         | 32968| 100%             | 356                    | 100%                                 |                     |

Based on the calculation results in Table 4, the normalization value results show the technical language "carrying out technical analysis" has the highest value of 38%. This technical analysis has a strong degree of correlation with most of the quality and pipe maintenance attributes, so management should consider implementing technical analysis as an effort to improve the quality of pipe maintenance.
Based on the results of HOQ that have been prepared, this study proposes pipe maintenance based on MQFD. The following is the technical proposal for pipe maintenance:

1. Carry out a system monitoring program in the form of checks related to the suitability of pressure, temperature, work cycle, etc.

2. Always ensure standard operating procedures by following the operating conditions, design specifications, standards, or regulations that apply to ensure the process of start-up, operation, and shutdown of equipment is carried out.
3. Routinely carry out inspections and checks of the main and supporting components of the pipe.
4. Routinely checking conditions such as gas pressure, temperature, regulator, CP system performance, etc. Then, compare it with the applicable tolerance limits.
5. Implement preventive maintenance programs, and improve the field security system as an effort to prevent the occurrence of vandalism.

4. Conclusion
Based on the results of the research discussion and analysis, the following conclusions can be drawn:
1. Based on the results of the analysis of TPM parameters in pipe maintenance in the field, it is known that the critical path of pipe maintenance quality is found in pipes with PL-B-003-2 "tag number. So, pipes with tag number PL-B-003-2" require more regular monitoring and maintenance to prevent breakdowns. The TPM parameter value also states that the performance of existing flowline maintenance meets world standards with an average OEE value of 86%. However, other supporting components of pipeline maintenance still need to be improved, this is related to reports of leakage, pipe damage, and vandalism in the field.
2. Based on the results of the identification of the pipe maintenance attributes, the attributes that become a priority in maintenance, including the implementation of daily inspections related to pipe conditions, corrosion monitoring, leakage conditions, etc. Also besides, there is also a need to improve compliance with management standards and methods such as improving operator specifications, O&M procedures.
3. From the results of the discussion of the house of quality, obtained a technical proposal for pipe maintenance, including carrying out a system monitoring program in the form of checks related to the suitability of pressure, temperature, work cycle, etc.; always ensuring standard operating procedures by following the operating conditions, design specifications, standards or regulations that apply to ensure the equipment start-up, operation, and shutdown are carried out; routinely carry out inspections and checks of the main components and supporting components of the pipe; routinely carry out checking conditions such as gas pressure, temperature, regulator, CP system performance, etc. Then, compare it with the applicable tolerance limits; carry out PM programs; improve the field security system as an effort to prevent the occurrence of vandalism.

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