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Integrity Assessment of Pipelines Failures

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Abstract: The proactive maintenance of pipelines through condition based monitoring, plays an essential role in improving their overall reliability and availability. Their criticality can also be assessed by conducting reliability analysis such as FMECA, which helps in identifying relevant failure modes and averting catastrophic failures to sustain economic growth.
This paper will focus on an integrity assessment set up for pipelines and the potential failure modes associated are evaluated and mitigated by determining the risk triggers.
The outcome of this research has shown the various threats associated with pipelines, having an effective integrity assessment program will help mitigate such threats.
Keywords: Risk Assessment, Corrosion, FMECA, Risk Priority, Failure, Inspection, Regulations, Pipelines, Monitoring

I. INTRODUCTION

Integrity assessment of pipelines has become one of the most reliable means of managing the numerous ranges of failures that may arise from its design phase down to the operational life cycle of the pipelines.
Globally, pipelines are regarded as the most effective means of transporting petroleum products from their production facilities to their distribution retailers. Furthermore, these pipelines serve as a conduit in providing the needed fuels for transportation, generation of power, and heating system as analyzed by [1].
Pipeline's failures pose a great financial loss to the business and gigantic damage to the host communities and injury to its people, consequently, having a safe pipeline network does not exclusively depend on its design and operations but largely depends on the maintenance practice and strategy that is put in place.
Pipeline failures as emphasized by Achebe et.al [2] have become a heightened issue because most organizations do not have an appropriate guideline for the design and operations of most oil pipelines.
This research will center on the comprehensive integrity assessment of pipelines to determine the procedure for pipeline management and ways to mitigate associated failures.
Pipeline failure rates have been on an increase over the years when compared to other oil-producing countries. As recorded by NNPC [3], it shows that over twenty pipeline failure cases were documented in the year 2007. Furthermore, the number of pipeline failures rose to thirty in the following year as stated.
Considering the high rate of pipelines failures in Nigeria, it will be beneficial to the Oil and Gas, miining, and energy Industries to have an effective integrity assessment program by adopting a cradle to grave asset integrity management process such as reliability centered maintenance to avert such failures.

II. PIPELINE CLASSIFICATION

The pipeline can be classified as a network of associated segments which includes pumps, valves, control devices, and other needed equipment for operating the system. [6], however, pipeline as defined by [8], is the connection of components namely (pipe, valves, pump, etc.) used in the conveyances of hydrocarbon.

Furthermore, [7], classified offshore pipelines into various categories as shown below:

1) Export Pipelines (Transportation from production facilities to onshore)
2) Production Pipelines
3) Flowlines (Transfer product from platform to export lines)
4) Flowlines (In the field)

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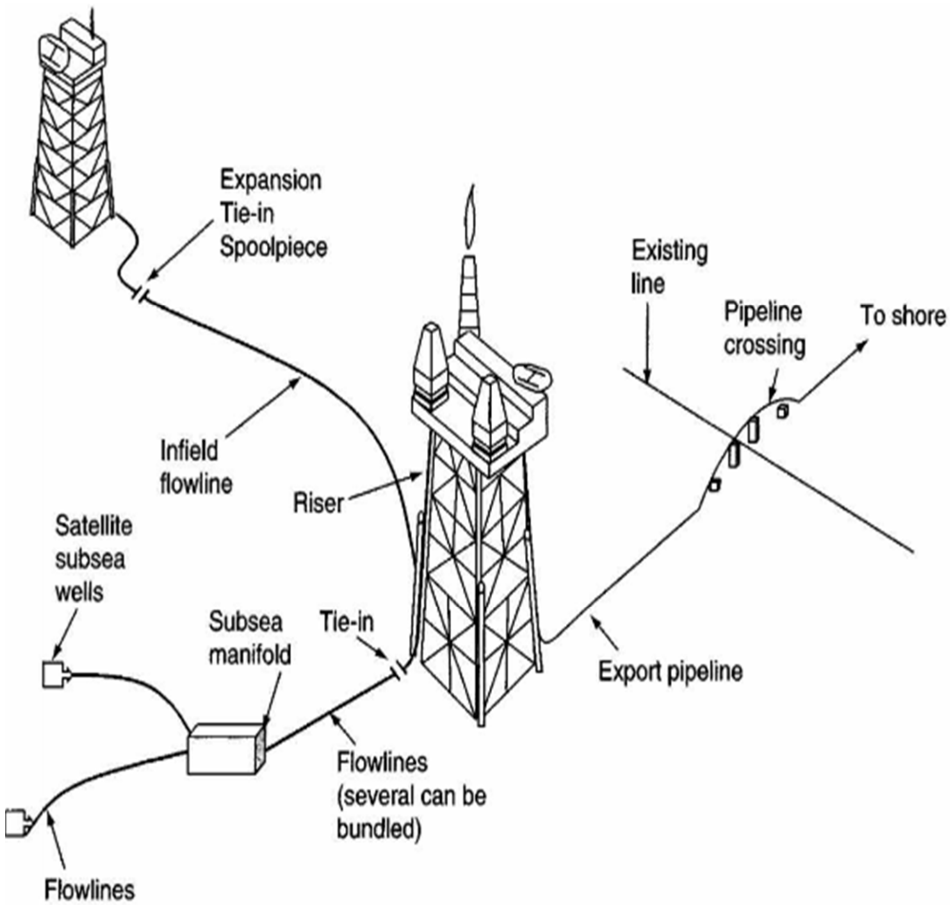

Figure 1: Classification of Offshore Pipelines

A. Integrity Assessment Process for Pipelines

The approach for an effective integrity assessment for pipelines was established to account for the pipeline integrity assessment from its concept phase down to its operational life cycle [4]. Pipeline integrity assessment program involves four essential components namely:

1) Risk assessment and IM Planning
2) Inspection, Mitigation & Testing
3) Integrity Assessment
4) Mitigation, Intervention & Repair

The effectiveness of the integrity assessment relies solely on the implementations of the four essential components.

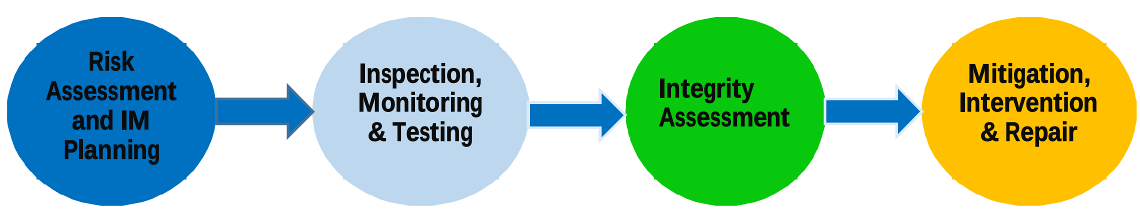

Figure 2. The Integrity Assessment Process for Pipelines

B. Risk Assessment and IM Planning

Risk assessment and IM planning is a life cycle procedure that is determined at the concept stage down to its operational stage and monitored throughout the life cycle of the pipeline.

This essential component of the integrity assessment process plays a major role in identifying and evaluating all potential threats, and risk decrease methods are introduced. The risk assessment is implemented from the design phase, down to the operational life of the pipelines and these risks can be Evaluated through quantitative or qualitative methods as examined by [5].

Characteristics	RBI Approach	
	Quantitative	Qualitative
Basis of Analysis	Direct estimation of risk value based on data	Experts Judgment
Result of Analysis	A numerical value of risk level	Risk level or Risk Index (low, medium, high)
Advantage	▪ Not based on subjective Judgment ▪ More detailed	Can still be done even with insufficient data
Disadvantage	▪ Not practical for complex system	▪ Only provide a broad categorization of risk. ▪ Not a detailed method
Example	Fault tree, Monte Carlo Simulation	FMECA, HAZOP, Risk Matrix

Table 1. Quantitative and Qualitative Approach

C. Inspection, Monitoring & Testing

The outcome of the *risk assessment and IM planning* gives birth to the control measures that need to be implemented for the safe operations of the pipelines. The inspection and monitoring process covers all pipeline maintenance scope which is further sub-divided depending on the nature of the threats identified.

As the name implies, inspection relates to evaluating the physical condition of the component/assets, while the extraction of real-time data from the equipment is denoted as monitoring which will enhance the trending of these results collected over time.

The data collected and inspections performed play a major role in the life of the pipeline, hence an effective risk assessment is carried, and non-conformity is documented.

D. Integrity Assessment

Integrity assessments are performed to determine the actual condition (integrity) of an asset, to evaluate the level of damage or defects. The observed defects and impacts on the pipelines are assessed and reported. Such reports are followed up with effective mitigation plans and execution.

The kind of threats noticed will determine the methods of assessment to be deployed in mitigating such threats such as Corrosion assessment (Internal & External). Each integrity assessment activity carried out must be documented to reflect the new data captured from the assessment and to serve as a reference point for upcoming integrity assessment exercises.

E. Mitigation, Intervention & Repair

Mitigation is a process of decreasing the likelihood and consequences of failure, while intervention deals with corrective measures, however, intervention should only be done in line with applicable standards and appropriate approval (management of change). Repairs of assets failures are done to restore the asset into service and to maintain its structural integrity.

F. Pipeline Integrity Assessment Framework

The pipeline integrity assessment framework for achieving reliability, availability of the pipeline entails the following:

1) Pipeline Identification
2) Threat’s evaluation and risk assessment using FMECA
3) Break down of the pipeline system
4) Quantitative criticality assessment using risk priority number (RPN)

5) Establish Criteria for criticality analysis
6) Develop Risk acceptance criteria (Design, Fabrication / Manufacturing, Construction / Installation and Operation / Maintenance)
7) Comparing the existing and revised RPN
8) Ranking of the revised RPN
9) Mitigation and Integrity assessment of failure modes greater than the established risk acceptance level.
10) Ensure the pipeline is properly analyzed, and all threats evaluated, otherwise repeat the process from risk assessment.
11) Documentation.
12) Plan the next inspection and repeat the process.

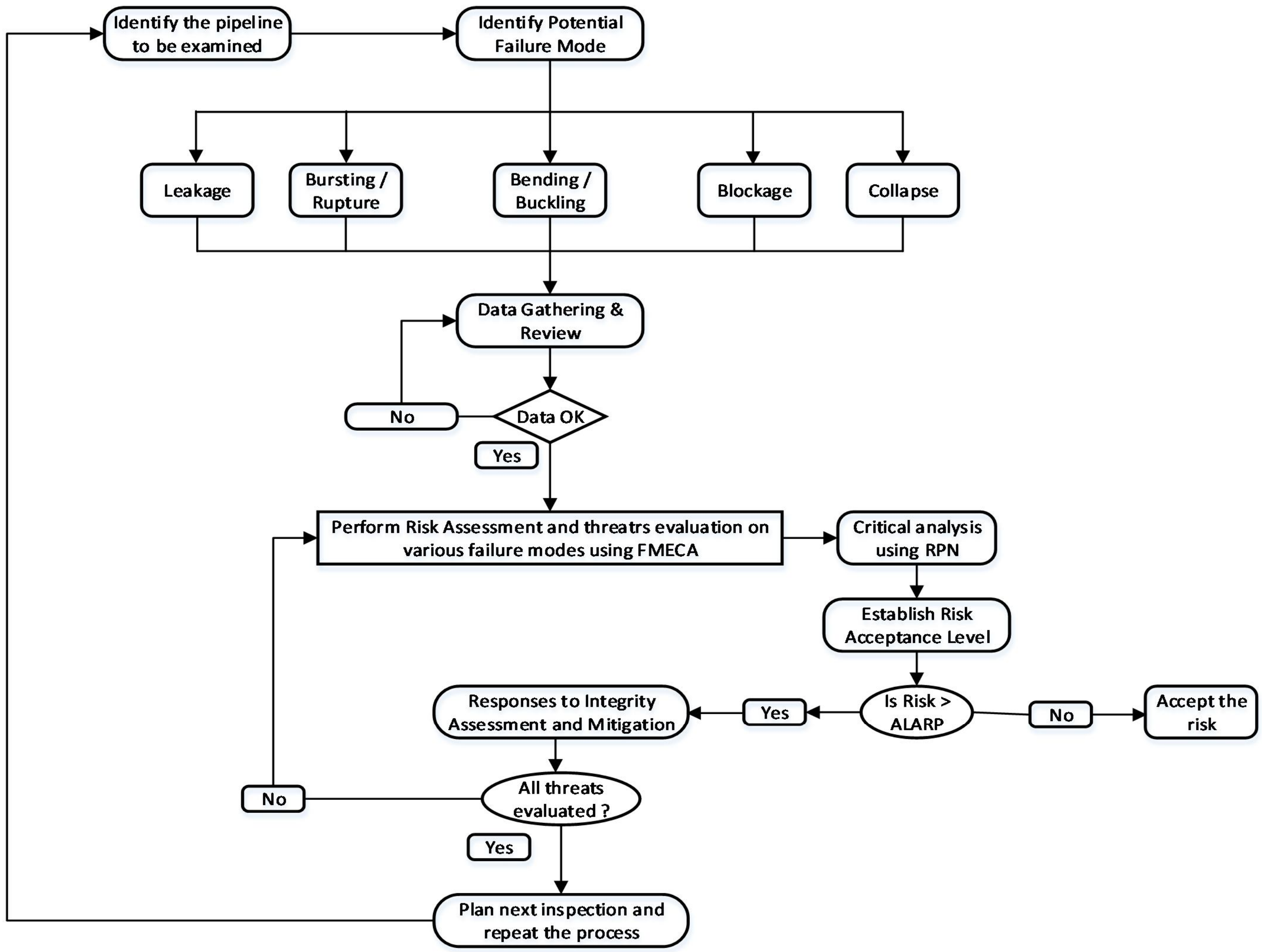

Fig 2: Framework for Pipeline Integrity Assessment

G. Threats Evaluation and Risk Assessment Using FMECA

Threat evaluation and risk assessment will be done simultaneously concurrently using Failure Mode Effect and Criticality Analysis (FMECA) on the pipeline.

Asking the right questions while performing FMECA will influence the result outcomes and enable us to understand the failure modes associated with the pipeline in operations. The questions to be asked include:

1) What are the basic functions and associated standards for its current operations (Functions)
2) In what capacity can it fail to meet his functions (Functionality failures)
3) What are the causes of each failure (Failure mode)
4) What occurs after each failure (Failure effects)

H. Criticality Analysis

Performing the criticality analysis through a quantitative approach entails using the Risk Priority Number (RPN) assigned to each failure mode. The RPN for each failure mode can be achieved using the formula below:

RPN = *Severity x Probability of Occurrence x Detectability*

III. CRITERIA FOR CRITICALITY ANALYSIS

The table below shows the various criticality analysis.

Severity		Occurrence		Detectability	
Hazardous	10	Extremely high	10	Absolutely uncertain	10
Serious	9	Very high	9	Very remote	9
Extreme	8	Repeated failures	8	Remote	8
Major	7	High	7	Very low	7
Significant	6	Moderate high	6	Low	6
Moderate	5	Moderate	5	Moderate	5
Low	4	Relatively low	4	Moderately high	4
Minor	3	Low	3	High	3
Very Minor	2	Remote	2	Very high	2
None	1	Nearly Impossible	1	Almost certain	1

Table 2: Criticality Analysis Table

IV. CONCLUSIONS

Pipeline integrity management system plays an important role in the life of the pipeline assets, as seen in this research, hence evaluation of the threats and results from the application of the pipeline integrity management system will adversely decrease anomalies in the lifecycle of the pipeline.

In all, integrity management of pipelines has been established to be an effective tool for the prevention, mitigation, and detection that will lead to availability, reliability, and safe operations of pipelines, therefore, turning a benefit to the host industries and countries in the increase reliability of the sites, avoiding high costs for unplanned maintenance and revenue losses.

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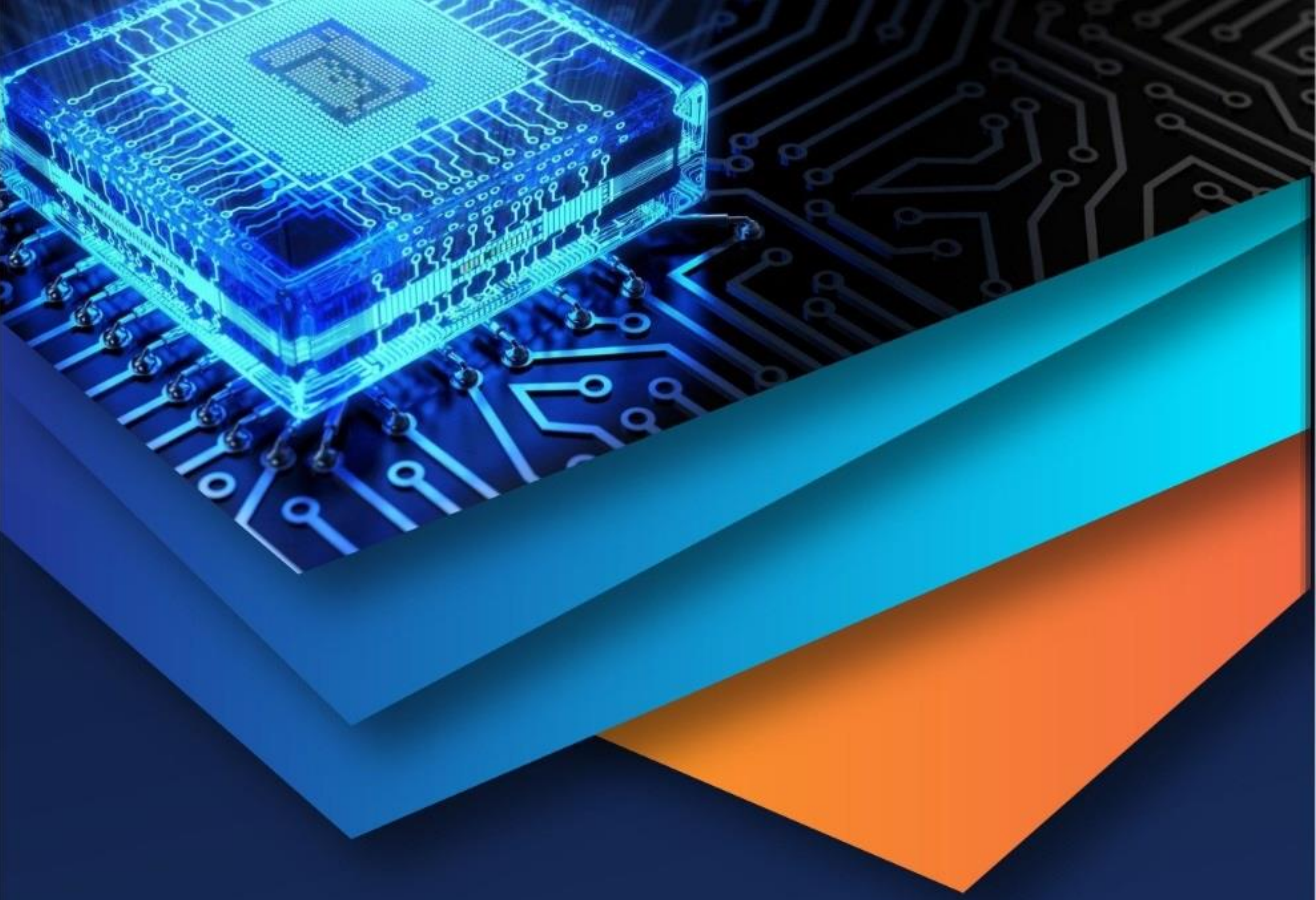

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