Neural Network Precept Diagnosis on Petrochemical Pipelines for Quality Maintenance

S.Bhuvaneswari 1* R.Hemachandran 2 R.Vignashwaran 3
1. Reader, Department of Computer Science, Pondicherry University, Karaikal Campus, Karaikal
2. Faculty, N.I.T, Puducherry
3. Scholar, Department of Computer Science, Amrita University, Coimbatore
* E-mail of the corresponding author: booni_67@yahoo.co.in

Abstract
Pipeline tubes are part of vital mechanical systems largely used in petrochemical industries. They serve to transport natural gases or liquids. They are cylindrical tubes and are submitted to the risks of corrosion due to high PH concentrations of the transported liquids in addition to fatigue cracks. Due to the nature of their function, they are subject to the alternation of pressure-depression along the time, initiating therefore in the tubes’ body micro-cracks that can propagate abruptly to lead to failure by fatigue. On to the diagnostic study for the issue the development of this prognostic process employing neural network for such systems bounds to the scope of quality maintenance.

Keywords: Percept, Simulated results, Fluid Mechanics

1. Introduction
The pipelines tubes are manufactured as cylindrical tubes of radius R and thickness e. The failure by fatigue is caused by the fluctuation of pressure-depression along the time \( t \) \( (0 \leq P \leq P_0) \). These pipelines are unfortunately usually designed for ultimate limits states (resistance). To be more realistic, a prognostic model is proposed here based on analytic laws of degradation by fatigue (Paris’ law) in addition to the cumulative law of damage (Miner’s law). This prognostic model is crucial in petrochemical industries for the reason of favorable economic and availability consequences on the exploitation cost.

2. Paris Law
The Paris’ law allows determining the propagation speed of the cracks \( \frac{da}{dN} \) at the time of their detection: \( \frac{da}{dN} = C.\left(\Delta K\right)^m \) where \( a \) is the crack length, \( N \) is the number of cycles, \( C \) and \( m \) are the Paris constants, and \( \Delta K \) is the stress intensity factor.
We can distinguish:
- The long cracks that obey to Paris law
- The short cracks that serve to decrease the speed of propagation

Fig. 1: Internal pressure diagram.
The short physical cracks that serve to increase the speed of propagation

The law can be written also as:

$$
\log \left( \frac{da}{dN} \right) = \log C + m \log(\Delta K)
$$

A tube is considered thin when its thickness is of the order of one tenth of its radius: $e \leq R/10$

Fig. 2: The three phases of cracks growth, Paris' law.

3. Pipelines under Pressure

A tube is considered thin when its thickness is of the order of one tenth of its radius: $e \leq R/10$

Fig. 3: Cylindrical pipelines

Fig. 4: Stress type distribution

4. State of Stresses

Te tubes are cylindrical shells of revolution. when thin tubes of radius $r$ and of thickness $e$ are under internal pressure $p$, the state of stresses is membrane-like under bending loads. the membrane stresses are
circumferential (hoop stress) $\sigma_\theta$ and longitudinal stresses (axial stress) $\sigma_L$.

These stresses are given by:

$$\begin{align*}
\sigma_\theta &= \frac{PR}{e} \\
\sigma_L &= \frac{PR}{2e}
\end{align*}$$

which are perpendicular to maximal stresses $\sigma_\theta$, that means longitudinal cracks which are parallel to the axis of the tube. A crack is of depth $a$ or of length $a$, if we measure in the direction of the tube thickness $e$. Normally the ratio $a/e$ is within the following range: $0.1 \leq a/e \leq 0.99$.

The stress intensity factor $K_I$ represents the effect of stress concentration in the presence of a flat crack.
Fig. 8: Non-uniform distribution of stresses near the crack

The stress intensity factor is given [6] by:

$$K_I = y(a)\times\sqrt{\pi a} \; \sigma_0$$

$$\Rightarrow K_I = 0.6 \times g(a)\times\sqrt{\pi a} \times P \times \frac{R}{e} \leq K_{IC}$$

with $Y(a) = 0.6 \times g(a)$: is the geometric factor.

$$K_{IC} : \text{is the tenacity of material (critical stress intensity factor)}$$

$$K_I : \text{is given by:}$$

$$\frac{J_{IC} \cdot E}{1 - (\nu)^2}$$

Note that the factor $K_I$ must not exceed the value of $K_{IC}$.

5. Proposed Percept Model

Consider a pipeline of radius $R = 240$ mm and of thickness $e = 8$ mm transporting natural gases, the parameters related to materials and to the environment are taken as being equal to:

$[5] \; m = 3 \; \text{et} \; C = \varepsilon = 5.2.10^{-13}$

The length of the crack is denoted by $a$ with an initial value $a_0 = 0.2$ mm $a_0 \leq a \leq a_N = \frac{e}{8} \Rightarrow \frac{e}{a_N} = 8$

We have to respect the following ratio:

$$0.1 \leq \frac{a}{e} \leq 0.99 \Rightarrow 1.01 \leq \frac{e}{a} \leq 10$$

Take a similar form to $\frac{da}{dN}$ as $\dot{a} = \varepsilon \phi_1(a) \phi_2(p)$

with: $\varepsilon = C$; $\phi_1(a) = \left(Y(a)\sqrt{\pi a}\right)^m$; $p = \Delta \sigma$ and $\phi_2(p) = p^m = (\Delta \sigma)^m$

The initial damage is: $a(0) = a_0$

A recurrent form of crack length gives:

$$D_i = D_{i-1} + \eta \phi_1(D_{i-1}) \Phi_2(p_i)$$

for $m = 3 \Rightarrow \Phi_2(p_i) = p_i^3 = (\Delta \sigma \theta_i)^3$

Moreover $\eta = \frac{\varepsilon}{a_N - a_0}$
We define the damage fraction by:

\[ d_j = \frac{da_j}{a_N - a_0} \]

Therefore, we get the cumulated total damage:

\[ D_i = \sum_{j=1}^{i} d_j = \sum_{j=1}^{i} \frac{da_j}{a_N - a_0} = \frac{\sum_{j=1}^{i} da_j}{a_N - a_0} = \frac{a_i}{a_N - a_0} \]

We can easily prove that:

\[ D_N = \sum_{j=1}^{N} d_j = 1 \]

Fig. 9: Miner’s law of damage

where:

\[ 0 \leq n \leq N, \quad a_0 \leq a \leq a_N; \]

\[ D_0 \leq D \leq 1 = D_N; \quad D_N = \sum_{j=1}^{N} d_j = 1 \]

\[ D_0 = \frac{a_0}{a_N - a_0} \Rightarrow a_0 = \frac{D_0 a_N}{1 + D_0} \]

The other sequences are:

\[ D_1 = \frac{a_1}{a_N - a_0} \]

\[ D_2 = \frac{a_2}{a_N - a_0} \]

\[ \vdots \]

\[ D_n = \frac{a_n}{a_N - a_0} \]
6. Percept simulation of levels

![Triangular simulation of internal pressure](image)

Fig. 10: Triangular simulation of internal pressure

<table>
<thead>
<tr>
<th>Pressure mode</th>
<th>Mean of $p_i$ ($\bar{p}_i$ in MPa)</th>
<th>C.o.v. of $p_i$ in %</th>
<th>Law</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (mode 1)</td>
<td>8</td>
<td>10%</td>
<td>Triangular</td>
</tr>
<tr>
<td>Middle (mode 2)</td>
<td>5</td>
<td>10%</td>
<td>Triangular</td>
</tr>
<tr>
<td>Low (mode 3)</td>
<td>3</td>
<td>10%</td>
<td>Triangular</td>
</tr>
</tbody>
</table>

We study three levels of maximal pressures in pipelines which are: 3 MPa, 5 MPa, and 8 MPa that are repeated within a specific interval of time $T=8$ hours. At each level, we deduce the degradation trajectory $D$ in terms of time or in terms of the number of cycles $N$. The failure by fatigue is obtained for a certain critical number of cycles: pressure-depression or for a certain time period. Therefore, the lifetime of the pipeline for each level of maximal pressure is deduced at $D=1$.

7. Results and Discussion on Simulation

The Monte Carlo one level percept simulations for 1000 times for the pipeline system and under the 3 modes of internal pressure (high, middle and low) gives the degradation trajectory which are represented in the following 3 figures.
Fig. 11: Degradation evolution for mode 1

Fig. 12: Degradation evolution for mode 2
We deduce from the percept interrogation that the pipeline lifetime is nearly 115 hours for mode 1 (high pressure), nearly 160 hours for mode 2 (middle pressure), and nearly 240 hours for mode 3 (low pressure). From these curves, we can see that our prognostic model, using analytic laws, gives the remaining lifetime...
of pipelines at any instant.

8. Conclusion and Scope for Future Work

The percept neural network sustains in predicting the life time effectiveness on field efficiency for the radial pipelines by which the user is able to read the rear and bear happenings on fluid mechanics in industries. The study also helps in predicting the sustainability feature of turbines in heavy alloy plants which could be scope for the work in future.

References


K. El-Tawil, S. Kadry, Fatigue Stochastique des Systèmes Mécaniques Basée sur la Technique de Transformation Probabiliste, internal report, Lebanese University, grant research program, 2010.


This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE’s homepage: http://www.iiste.org

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. **Prospective authors of IISTE journals can find the submission instruction on the following page:** http://www.iiste.org/Journals/

The IISTE editorial team promises to the review and publish all the qualified submissions in a fast manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request of readers and authors.

**IISTE Knowledge Sharing Partners**

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digital Library, NewJour, Google Scholar