

Failures Prediction of Pipelines Carrying Natural Gas Using Bees Algorithm

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The purpose of this research is to predict failures (corrosion, cracks, laminations, joins or others) in pipelines carrying natural gas. Using the Bees Algorithm based on the behavior that is performed in nature. The obtained results show the systematic occurrence of faults, which implies the need for preventive maintenance in pipelines to keep infrastructure and population security.

Introduction

Many complex engineering problems cannot be solved exactly with polynomial computation, so in recent years evolutionary algorithms have been implemented for global search and optimization, which offer advantages such as simplicity and easy implementation, general purpose permit an effective global search based on the selection of the best solution from each population. (1)

The search for a global solution using evolutionary algorithms based on population to converge at the optimum, it includes the Ant Colony Optimization (ACO), Genetic Algorithms (GA's), Particle Swarm Optimization (PSO) and Bees Algorithm (BA). In particular the latter has several characteristics that identify, such as: a relatively low convergence time, a small number of parameters to configure and simple heuristics. (2 and 3)

The BA mimics the behavior in the nature of the swarms of honeybees during foraging, and this performs a combination of local and random global search, able to find efficient solutions to the proposed problem. (4)

Pipelines usually have faults along its route for the transportation of natural gas, making it necessary to use tools for predicting the occurrence of faults at specific points in a given segment, which is why it needs an algorithm to restrict the search criteria to find the optimal solution.

The main faults in pipelines can be of chemical and/or electrochemical nature, manifested through corrosive or physical processes shown through cracks, laminations, or other joints.

In the Petroleum Industry, it is often used the API 5L X-70 steel for construction of pipelines which exhibit frequent failures, if this is timely predicted may prevent human and economic losses and ecological damage. (5)

Methods and Materials

Recorded data are obtained by a group of researchers of CIATEQ (Centro de Investigación y Asistencia Técnica del Estado de Querétaro, A.C.), which uses a magnetostrictive sensor to quickly determine the defects in pipeline structures. The operating principle is based on the emission of guided waves applied to the pipes (Figure 1).

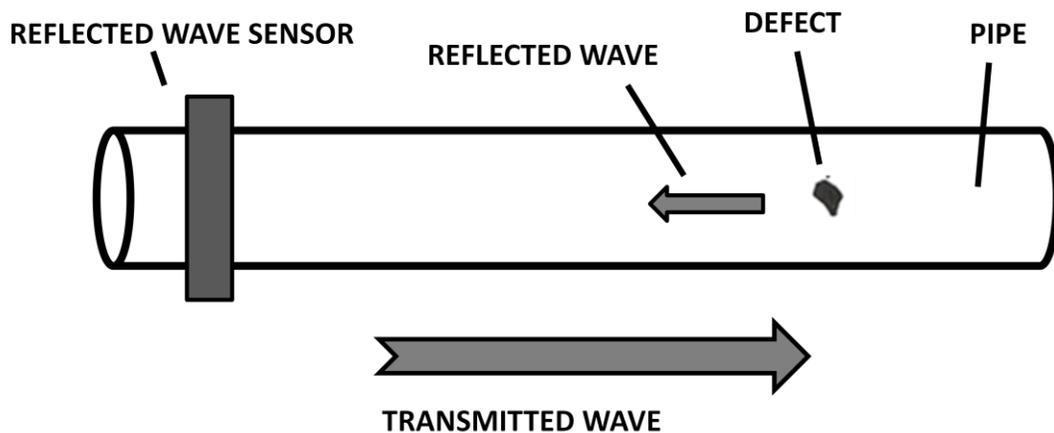


Figure 1. MsS Technology Applied in Pipelines Inspection Using Ducting Waves in Pipelines (6).

Data obtained (6) are shown in Table I, which include distance, specified percentage and type of defects.

Table I. Inspection report generated by the system. (6)

No	Symbol	Distance	% Defect	Class
1	w1	2.17	10	Weld
2	d1	3.75	5.11	Defect
3	X	11.37	1.87	Direccionalidad
4	w2	15.62	10	Weld
5	d2	20.22	6.72	Defect
6	d3	25.36	2.96	Defect
7	d4	25.98	3.05	Defect
8	d5	26.33	3.39	Defect
9	ew	29.07	17.08	Elbow Weld
10	ew	29.53	4.84	Elbow Weld

These data are obtained in sections of 35 meters of pipeline of 36 inches in diameter made of API 5L X-70 steel whose composition is shown in Table II, in an area of central Mexico.

Table II. Nominal composition of API 5L X-70 steel, expressed in% weight. (7)

C	Mn	Si	S	P	Al	Nb	Cu	Cr	Ni	Ti	Ca	N ₂
0.037	1.50	0.14	0.003	0.015	0.03	0.09	0.27	0.26	0.16	0.010	0.0025	0.0040

Based on these data BA is applied, which is restricted by an objective function that includes parameters for failures prediction in the pipeline, the optimal solution is obtained with a combination of global search and local search in the solution space.

It uses the algorithm described in the flow chart shown in Figure 2.

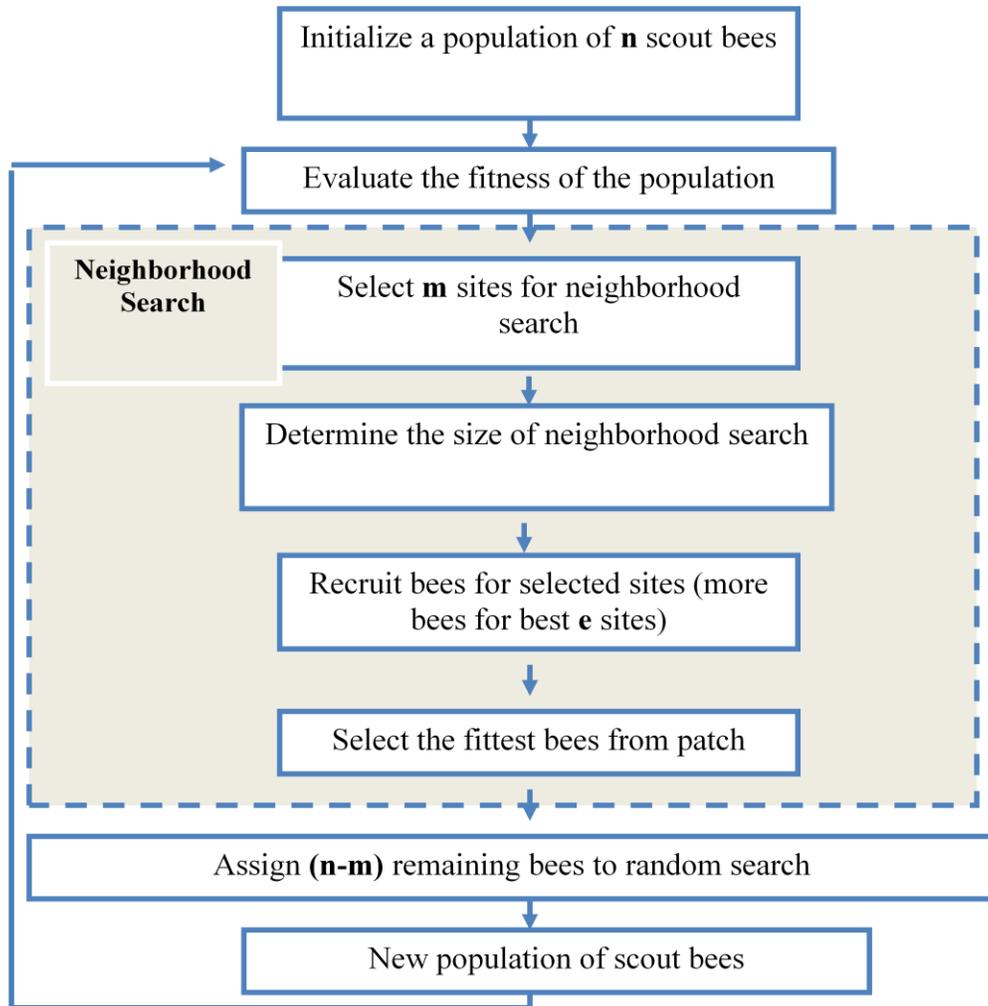


Figure 2. Flowchart of Bees Algorithm (4)

Where the parameters of the algorithm are:

n = Number of scout bees.
e = Number of elite bees.
m = Number of points selected sites visited.
nes = Number of bees used to visit elite sites.
nsp = Number of bees used for other selected sites.
ngh = Size of the site.
Stop Criteria = Number of iterations.

All global search algorithm based on population requires an objective function (**A**) which represents the task to be solved in the evolutionary context and it guides the algorithm in the search for the optimal solution. The evaluation of **A** allows a heuristic estimation of the real solution, because that is the link between the optimization method and the problem to be analyzed. In this particular problem of failures prediction in pipelines, the values of positions and extents of the faults determined are included in the equation 1, which is minimized using BA.

$$A = \sum_{\omega=1}^n p_1(\omega) |f_e(\omega) - f_d(\omega)| + p_2(\omega) \quad [1]$$

Three necessary and sufficient conditions are:

$$f_d(\omega) = \begin{cases} 0, & \textit{otherwise} \\ f_d, & \omega = \omega_{i=1,..n} \end{cases}$$

Where **n** is the number of faults identified and $f_e(\omega)$ is the prediction failures vector, which is coded by a bee and in the beginning is randomly generated next to the desired solution

$$p_1 = 30, \quad \textit{for } \omega = \omega_i$$

$$p_2 = \begin{cases} 5, & f_e < 10 \\ 0, & \textit{otherwise} \end{cases}$$

Where $f_e(\omega)$ and $f_d(\omega)$ are functions estimated by BA and measured by the magnetostrictive sensor, respectively. And $p_1(\omega)$ and $p_2(\omega)$ are weighs included in **A** to control the position and extent of the faults respectively, which are chosen from experience in the use of this optimization algorithm.

The proposed algorithm was programmed in Matlab 7.10 simulation platform where you get the graph corresponding to the optimal solution found.

Results and Comments

Figure 3 show the behavior of failure rate in the section of pipeline sampled, which presents the existence of high percentages of those above the threshold between 2 and 3%. (6)

Importantly, the highest failure rate occurs in the location of the fixtures and fittings of the system and not caused entirely by nature corrosive chemical and/or electrochemical processes, which show resistance to the environment (natural gas) that presents the API 5L X-70 steel used for pipelines construction.

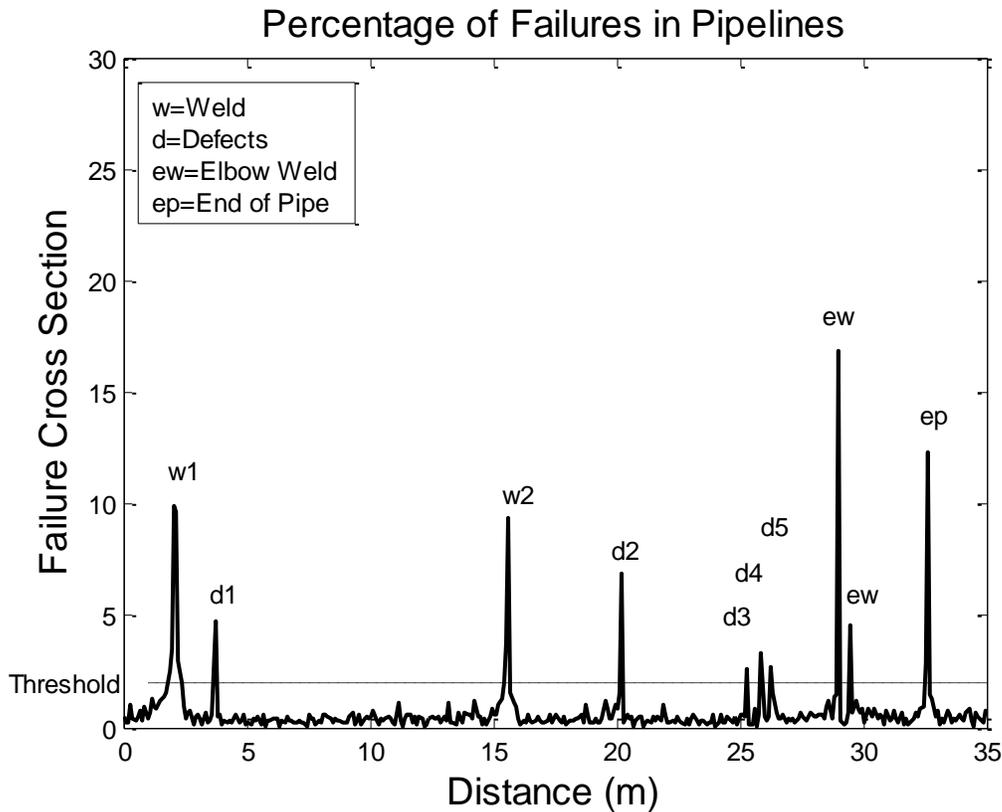


Figure 3. Results of the failures prediction using BA.

The results obtained by BA, shown in Figure 3, are similar to those reported by using magnetostrictive technology, which indicates that this kind of algorithm is a reliable and valid technique for prediction.

All the above allows for a prediction tool with a fast convergence time, without destructive testing, of easy application and implementation of failures in pipelines carrying natural gas.

Conclusions

We show that using evolutionary computing, in particular BA, it is possible to predict the behavior of faults in pipelines carrying natural gas with the advantage of lower costs compared to other detection methods and have a fast convergence time.

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