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A Computer-Assisted Crack Predicting System for Oil and Gas Pipelines Using Fuzzy Cognitive Map

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Abstract: This paper presents a computer-assisted possibility of crack predicting system for oil and gas pipelines, which aids the non-expert to predict the causes of corrosions, crack and its level at the level of an expert in the general inspection of structures. The system presented in this paper adopts fuzzy cognitive mapping to reflect fuzzy conditions, both for corrosion symptoms and for cracks, which are difficult to identify. The inputs to this system are some numeric data about the corrosion, stress, environmental conditions and some linguistic variables concerning the crack symptoms. The numerical values of the parameters which define the mechanical and chemical properties of the pipes and the medium that flows are affected by several sources. Using these input data and based on built-in rules and the inference, the proposed system predicts to identify the crack causes under different conditions. The built-in rules and the inference were constructed by extracting expert knowledge, primarily from technical books about corrosions, stresses and cracks due to corrosion and stresses. At the point when connected to breaks really diagnosed by specialists, the proposed framework gave results like those got by specialists and we expect that this framework can be utilized as a powerful crack predicting device for both specialists and non-specialists in the online monitoring of pipes. After that, results compare with previous implementation methods, FCM method Correctly Classified Instances percentage is higher (94.66%).

Key words: Fuzzy Cognitive Map (FCM) · Hebbian learning law · Causes of Crack · Pipeline Age · Triangular Fuzzy Numbers (TFN)

INTRODUCTION

Oil and Gas transport is the most important things to supply in deciding the economy of a nation as these energies distributes unevenly throughout the world. The advancement of national economy is subject entirely to energy and its transport. With a perspective of the environment, security and supportable improvement, industrialized nations offer need to create oil and regular gas industry. Water and Pipeline transport are the two alternative modes to transport oil and gas, whose have their every qualities and abilities and between substitution. So that, particularly with the advancement of petroleum and regular gas industry and the bloom of pipeline transport since structural change of energy, to settle on choice and to tackle the issue of transport for oil and common gas by engineered examination of transport mode between conduit transport and pipeline, which plans to acknowledge oil and characteristic gas transport in a balanced manner, is hardly important. [1] Indian commercial ventures has been changed because of progression in computerization innovation that managing to adapt up the large scale manufacturing with smooth working condition. In an industry the vast majority of the machines is dealing with water driven frameworks which utilizes consistent channels for transmission of liquid through suction, conveyance lines and so on., Safe and useful operation are required in the piping network of hydraulic systems, as failure transmission can occur at various nozzles, joints and cracks may occur in pipelines due to corrosion and stresses. Corrosion and cracking on the outer or inside surfaces of in-administration pipes, tanks, or other modern resources decrease the trustworthiness of the material and possibly diminishes

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the administrative life of the supplies. Deformities may have different structures and may be started by one or more instruments conceivably bringing about erosion and/or splitting. These components influence an extensive variety of materials and extension numerous commercial ventures, including mechanical, aviation, pipeline, power era and marine.

Corrosion is the breakdown of the material because of electrochemical techniques where there is a trade of electrons between two materials. Corrosion can possibly lessen an item's configuration life from early corruption. Corruption of pipelines is the consequence of the determined assault by nature of pipeline materials. Covered pipelines are placed inside always showing signs of change, ecological conditions that may prompt a destructive domain. Elements that may avoid or add to the start and assault on covered pipelines are: Pipe Coatings, Cathodic protection, Soil Conditions, Temperature, Stresses, Pipe pressure, Cyclic loading effects and so on.

Types of Corrosion

General Corrosion or Uniform Corrosion: Uniform or general consumption, which is the least difficult type of erosion, is an even rate of metal loss over the uncovered surface. It is generally considered of metal loss because of chemical attack or disintegration of the metallic part into metallic particles. [1] In high-temperature circumstances, uniform metal loss is typically gone before by its mix with an alternate component instead of its oxidation to a metallic particle. Mix with oxygen to structure metallic oxides, or scale, brings about the loss of material. This corrosion will occur either internally or externally in the wall of the pipeline. Internal corrosion occurs when the corrosive liquids are transported through the pipelines.

Intergranular Corrosion: This corrosion is a localized form of corrosion. It is a particular physical attack on the grain boundary phases or the zones instantly adjoining them. Almost no assault is seen in the primary group of the grain. This will overcome the loss of quality and flexibility. The assaults are regularly fast, penetrating profoundly into the metal and bring disappointment.
It will propagate in two ways:

- Because it spreads within the grains, it called as transgranular corrosion, which propagates through all the directions. This will affect all the metallurgical constituents.
- The intercrystalline corrosion consumes only a small amount of metal, unlike corrosion, this follows a preferential path.

Galvanic/Bimetallic Corrosion: This is an electrochemical process happens electrically when two metallic materials are connected with the presence of an electrolyte like water. The most severe attack occurs at the joint between the two dissimilar metals. [1] Example, this corrosion is frequently qualified where modern copper piping is connected to existing carbon steel lines. The coupling of the carbon steel to the copper causes the carbon steel to corrode. Then the rest of the other surface, the surface which is affected by galvanic corrosion has a shinier aspect.

Crevice Corrosion: It is a localized form of attack, which form a gap between two metals or between metallic and non-metallic material. Crevice corrosion may happen on any metal and in any destructive environment. Even so, metals like aluminum and stainless steels that rely on upon their surface oxide film for corrosion resistance are especially inclined to Crevice corrosion, particularly in environments, for example, seawater that contains chloride particles. The material which form crevice need not to be a metallic thing, it may be Rubber, Wood, Glass, Plastic, or something else.

Pitting Corrosion: It is an extremely localized loss of metal. It's a tiny hole, which appears very deep in the affected area. The depth of the pit ultimately leads to a thorough hole or a huge undercut in the thickness of the metal part. The pit's width may increase with time, but not to the level to which the depth increases. Regularly, the pit opening remains covered with the corrosion product, making it hard to notice during the inspection. It produces a negligible amount of loss of weight, which gives little evidence of the damage.

Erosion-Corrosion: Erosion-Corrosion is the combined action involving erosion and corrosion in the presence of a moving fluid or a metallic component moving through the fluid, leading to speed up the loss of metal. The automatic effect of flow or velocity of a fluid coupled with the acidic action of the fluid can speed up the damage to the material. The early stage involves the automatic taking away of a material's protective layer and then the corrosion of uncovered metal by a flowing corrosive occurs. This process occurs cyclic until perforation occurs in the component. This kind of corrosion is usually found at high flow rates about blockages in tubes or in pump impellers.

Stress Corrosion Cracking: Stress corrosion is a type of crack which results from the combined action of corrosive environment and mechanical stress like bending and tension. The rate of propagation can vary to a great extent and is affected by stress levels, temperature and concentration of the corrosive action. This type of attack takes place in a certain medium. All metals are potentially under the focus of stress corrosion cracking. The conditions like suitable environment, tensile stress, appropriate temperature and sensitive metal are necessary for stress corrosion. The level of metal loss is directly proportional to the amount of stray current flowing through the system. The Underground pipes and storage tanks without CP systems are mainly susceptible to stray current corrosion.

Microbiologically Influenced Corrosion: Microbiologically influenced corrosion (MIC) is defined as corrosion that is influenced by the presence and activities of microorganisms, including bacteria and fungi. Microorganisms located at the metal surface do not directly attack the metal or cause a unique form of corrosion. The most aggressive attacks generally take place in the presence of microbial communities that contain a variety of types of bacteria. In these communities, the bacteria act cooperatively to produce conditions favorable to the growth of each species. For example, obligate anaerobic bacteria can thrive in aerobic environments when they are present beneath deposits in which aerobic bacteria consume the oxygen. In the case of underground pipes, the most forceful attack has been related to acid-producing bacteria in such bacterial communities.

Fuzzy Logic and Fuzzy Cognitive Map

Fuzzy Logic: The fuzzy logic shows up the most qualified apparatus for the transforming of numerical information and questionable data, keeping in mind the end goal to get a phonetic description of structural harm. [2] The fuzzy logic was presented in the 60's,it was expressed that the "key components of human thought can't be spoken to by numbers, but instead are the names of fuzzy sets, that is to say, phonetic qualities distinguishing fuzzy sets." Fuzzy sets are classes of articles described by a steady move from the enrollment condition to the non-participation one, though fresh sets (that where the one and only known before this new hypothesis) just permit the extreme double condition enrollment/non-participation. Subsequently, the hypothesis of fuzzy sets requires the meaning of an enrollment capacity ready to partner to every component of a set the journalist participation degree, which will be equivalent to 0 if the component does not have a place at all set and will be equivalent to 1 if the component fits in with the set. These two extremes, there is an extensive variety of fractional enrollment, spoke to by a genuine number included in the reach 0-1. It is simply the vicinity of a covering among distinctive sets that speaks to the key for taking care of the vulnerability and imprecision already said.

Fuzzy Cognitive Map: Fuzzy Cognitive Map (FCM) approach is a typical representation of the explanation and displaying of complex framework. [3] Fuzzy Cognitive Maps can be utilized to portray diverse viewpoints in the conduct of a complex framework regarding ideas; every idea speaks to a state or a normal for the framework and these ideas connect with one another demonstrating the motion of the framework. FCMs are a basic approach to depict the conduct in a typical way and can be utilized to represent the entire framework by a chart demonstrating the circumstances and end results along ideas, by abusing the amassed information of the framework.

A Fuzzy Cognitive Map incorporates the collected experience and information on the operation of the framework, as a consequence of the system by which it is built, i.e., using human specialists that know the operation of the framework and its conduct in distinctive circumstances. Moreover, Fuzzy Cognitive Map uses learning strategies, which have actualized in Neural Network Theory, so as to prepare Fuzzy Cognitive Map and pick proper weights for its interconnections. Fuzzy Cognitive Maps are Fuzzy marked diagrams with input [4]. They consist of node concepts C_i and interconnections W_{ij} between concept C_i and C_j. A Fuzzy Cognitive Map models an element complex framework as a gathering of concepts and source results relationships between concepts. A basic illustrative picture of a Fuzzy Cognitive Map is portrayed in Figure 1, comprised of five node concepts.

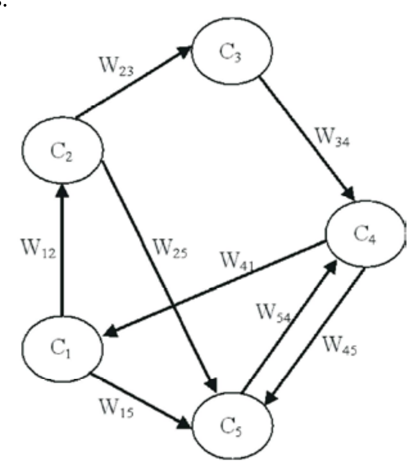

Fig. 1: Fuzzy Cognitive Map

It must be specified that the utilization of specialists is extremely basic in the outlining and improvement of Fuzzy Cognitive Maps. Specialists who have learned and experience in the operation and conduct of the framework are included in the determination of concepts, interconnections and relegating easy going fuzzy weights to the interconnections [5-6].

For the most part, Fuzzy Cognitive Maps can be prepared, utilizing learning calculations as a part of a comparable path as in neural systems proposition. Proposed learning calculations fit in with the unsupervised learning calculations. During the preparation time of FCM, the map weights are changed with a first-request learning law that is in light of the relationship or differential Hebbian learning law,

$$W'_{ij} = W_{ij} + X'_i X'_j$$

Therefore $x'_i x'_j > 0$, if values of concepts C_i and C_j travel in the same directions and $x'_i x'_j < 0$ if values of concepts Ci and C_j travel in the opposite directions. So the concepts which tend to be +ve or -ve at the same time period will have tough in +ve weights, while those that tend to be opposite will have tough in -ve weights.

Proposed Method

Fuzzy Cognitive Map Approach to Detect Crack: The FCM is suitable technique to cope with complex decision making tasks such as the prediction of crack, the severity of corrosion in oil and gas pipelines. It is simple, no time consuming and exploits experience and accumulated knowledge from experts. [7]. There are a number of factors, constraints that affect the pipes which lead to corrosion and later to crack. The main factors are corrosion and stresses. There are many constraints that have to decide while choosing materials for pipe. One is the type of gas or oil that is to be transported through it, next environment, whether it is too buried in soil or in water. The parameters that are considered are temperature, pressure, velocity, allowable stress, which is of two types, tensile stress and yield stress, vibration, relative humidity, pH, oxygen concentration, chloride, CO2, H2S and other organic compounds. The number and type of parameters-factors that cause corrosion and crack in oil and gas pipelines were defined by three experts and factors represented in Table 1 [7]. These factors assign the main variables that play an important role in the detection of cracks, corrosion rate and are the concepts of the FCM. The concept values can take two, three or four possible discrete or fuzzy values. Sixteen concepts are the factor concepts representing the main variables that the expert usually takes into consideration in assigning the existent and the grade of the corrosion and crack. The output (decision) concept represents the grade of crack and takes five fuzzy values (Very low, low, medium, medium high, very high) in Table 1.

Table 1: Concepts (Causes) represent the Impact on crack and takes fuzzy values

Concepts	Impact on crack	Description of concepts	Type of values
C_1:Temperature	High	If temperature increases, density of liquid /gas decreases	Normal(<750°F),High(>750 °F)
C_2:Pressure	Medium	If pressure increases, crack occurs	Normal(745 psi to 855),High(>855 psi)
C_3:Velocity	Medium	The velocity of a gas/liquid increases as Density of it decreases: Velocity increases, Flow accelerated corrosion may occur if Renold's number is greater than 2000	Normal (Re < =2000) High(Re > 2000(turbulent flow))
C_4:Vibration	High	If vibration increases, crack increases	Normal(=7000 cycles),High(>7000)
C_5:Density	Low	If density decreases, velocity increases.	Normal(<870 Kg/m$^{3)}$, low(870 Kg/m^3 to 920 Kg/m^3) Medium (920 Kg/m^3 to 1000 Kg/m$^{3)}$ High (>1000)
C_6:Yield stress	Medium	If yield stress increases, crack increases	Normal(<=35ksi),High(>35ksi)
C_7:Tensile stress	Medium	If tensile stress increases, crack increases	Normal(<=60ksi),High(>60ksi)
C_8:Relative humidity	Low	Relative humidity increases in soil, corrosion increases, which leads to crack	Normal (<=60%), High (>60%)
C_9:O2 concentration	Medium	The lowest concentration of oxygen in the liquid/gas is an early indicator of corrosion. If oxygen concentration is low compared to other organic compounds in gas/liquid, corrosion increases.	Low(0-0.4),Normal(0.3-0.7),High(0.5-1)
C_{10}:H+	Medium	If H+ increases corrosion increases, which leads to crack	Absent (0-0.4), Present (0.3-0.7),Intense(0.5-1)

Table 1: Continued

Concepts	Impact on crack	Description of concepts	Type of values
C_{11}:CO2	High	The partial pressure of carbon dioxide (pCO2) is also an indicator of the occurrence of corrosion. High values of pCO2 increase.	(0 -3 psi) very low, (3 to 7 psi) normal, (7 to 10) medium (corrosion), (>10 (crack) corrosion severe.
C_{12}:pH	Medium	It is an indicator that reflects the effectiveness of mechanism for regulating the acid-base status of the organism. It can be calculated by gas analysis. Three fuzzy values Acidosis <4.5, Normal 4.5-7, Alcakalosis >7	Low (<4.5), normal (=4. 5 to 7), high (>7)
C_{13}:H2S	High	If H2S increases corrosion increases, which leads to crack	Normal (0 to 3.5) and High (>3.5 (Corrosion occurs))
C_{14}:Chlorine	Low	If chlorine content in liquid or gas increases, So concentration increases	Absent (0-0.4), Present (0.3-0.7)Intense(0.5-1)
C_{15}:Corrosion	High	If corrosion increases, then crack increases, which lead to leakage or rupture. While choosing the pipe, the size is taken by considering the allowable corrosion rate. For Carbon steel pipe (A106 Grade B) allowable corrosion rate is 3mm)	Accepted (< =3mm),Moderate (3-4 mm), Severe(>4 mm)
O1:Crack		If crack is slight(low) it leads to pin hole, medium means leakage, severe leads to fracture or rupture	linguistic variables (low, medium, severe)

After the description of FCM concepts, every master was asked to define the degree of influence among the concepts and to describe their interrelationship using an IF—THEN rule, assuming the following statement where C_i and C_j are all the ordered pairs of concepts:

IF a {increase, decrease} change occurs in the value of concept C_i THEN a {increase, decrease} change in value of concept C_j is caused. So the influence of concept C_i on concept C_j is T (influence).

Then, experts inferred a linguistic weight to describe the cause and effect relationship between every pair of concepts. To illustrate how numerical values of weights are produced, the three suggestions on how to indicate the interconnection between concept and concept crack are shown below:

1st expert: IF there is an increase in the value of concept C_1, THEN an increase in value of concept C_{16} is caused. Infer: The influence from C_1 to C_{16} is very high.

2nd expert: IF there is an increase in the value of concept C_1, THEN an increase in value of concept C_{16} is caused. Infer: The influence from C_1 to C_{16} is medium high.

3rd expert: IF there is an increase in the value of concept C_1, THEN an increase in value of concept C_{16} is caused. Infer: The influence from C_1 to C_{16} is medium.

These linguistic variables (very high, medium high and medium) are summed and an overall linguistic weight is produced.

The defuzzification method of Center of Gravity is transformed into the numerical value of W_{16} =0.6157.

FCM representing Pipe Age: The proposed models use Triangular Fuzzy Numbers (TFN) [8], as these are frequently utilized for speaking to semantic variables because of their straight forwardness [9]. Figure 2 delineates the idea of the semantic meaning of channel age.

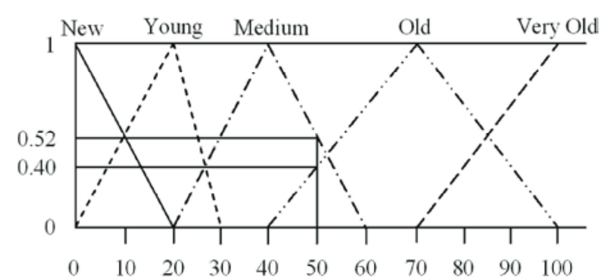

Fig. 2: FCM representing Pipe Age

In this illustration, it can be seen that for a channel of age 50 years the enrollment qualities are 0.52 and 0.40 to Medium and Old evaluations individually and zero enrollment to all different evaluations.

The Fuzzy set speaking to the covered channel at age 50 can be composed as a 5-component vector (0, 0, 0.40, 0.52, 0), in which every component portrays the channel's enrollment worth to the comparing subset of maturing evaluation (from new to exceptionally old).

Crack Diagnosis System: A Computer helped crack diagnosis system for strengthening Pipeline structures which help the non-master to diagnose the reason for a crack at the level of a specialist in the general review of structures. The system displayed adjusts FCM set hypothesis to reflect FCM conditions, both for split side effects and qualities which are hard to treat utilizing fresh sets. The inputs to the system are basically semantic variables concerning the split manifestations and any numeric information about cement and natural conditions [10]. Utilizing these info information and in light of inherent tenets, the proposed system executes FCM induction to assess the split causes under thought. The implicit tenets were built from extricating master information, principally from specialized books about pipeline cracks. We executed the proposed system in a computer program with a realistic client interface for real use in down to earth business fields. At the point when connected to cracks really diagnosed by specialists, the proposed system gave results like those got by specialists and we expect that this system can be utilized as a viable split conclusion apparatus for both specialists and non-specialists in the customary investigation of RC structures.

RESULTS AND DISCUSSIONS

Fuzzy Cognitive Mapping to reflect fuzzy conditions, both for corrosion symptoms and for cracks, which are difficult to identify. The inputs to this system are some numeric data about the corrosion, stress, environmental conditions and some linguistic variables concerning the crack symptoms. Here getting result from Matlab implementation using FCM Figure 3. After that, results compare with previous implementation methods, FCM method Correctly Classified Instances percentage is higher (94.66%) in Table 2.

Table 2: FCM Result Compare with Various Methods

Method	Classification	No. of instances	Percentage	Confusion matrix
bayes.NaiveBayes	Correctly Classified Instances Incorrectly Classified Instances	64 11	85.33 % 14.66 %	a b c 26 2 2 0 28 7 0 0 10
SOM	Correctly Classified Instances Incorrectly Classified Instances	65 10	86.66% 13.33%	a b c 27 3 0 0 35 0 0 7 3
FCM	Correctly Classified Instances Incorrectly Classified Instances	71 4	94.66% 5.33%	a b c 27 1 2 0 34 1 0 0 10

a → severe; b→ medium; c → low

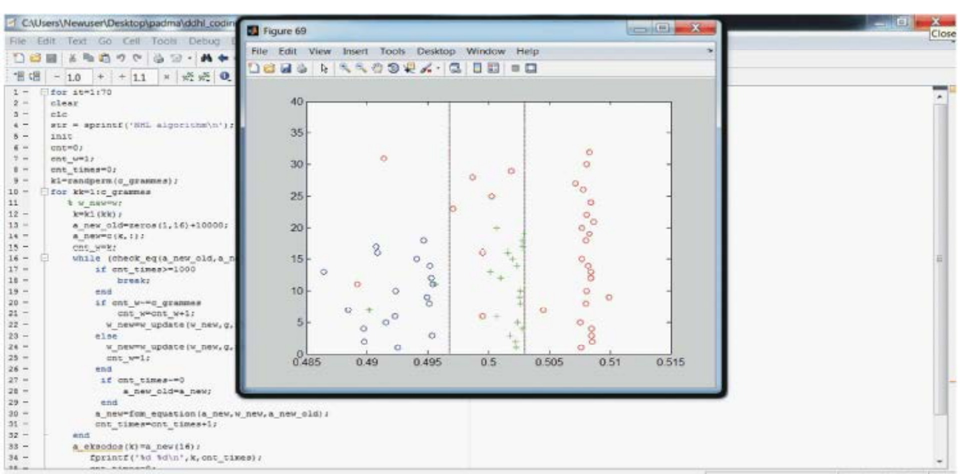

Fig. 3: Matlab Implementation of Crack Predicting using FCM

CONCLUSION

In this paper, Fuzzy Cognitive Mapping to reflect fuzzy conditions, both for corrosion symptoms and for cracks, which are difficult to identify. The inputs to this system are some numeric data about the corrosion, stress, environmental conditions and some linguistic variables concerning the crack symptoms. Pipeline age was calculated by FCM method that calculation also used for the pipeline crack diagnosis system. Finally FCM method is best implementation method, using for oil and gas pipeline crack diagnosis system. The Matlab implementation result given the FCM method percentage compares with various methods. FCM method Correctly Classified Instances percentage is higher (94.66%).

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