Application of Metal Magnetic Memory Testing Technology in Pipeline Defect

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Abstract. The metal magnetic memory testing technology can detect the stress concentration area of ferromagnetic materials, and then diagnose the micro defects and early damage. Based on the principle of artificial neural network, 3 single output three layer BP neural networks are designed by using metal magnetic memory testing technology. In this paper, the stress concentration, crack and other pipeline defects are detected and identified. The experimental results show that the recognition rate of pipeline defects is 97.5%.

Introduction

Ferromagnetic materials have been widely used in modern industries, such as oil and gas pipelines. Pipeline transportation plays an important role in the world oil and natural gas transmission. The safe operation of the pipeline is very important. Due to various loads, the stress concentration will occur in the process of pipeline operation, and then the fatigue damage or crack will occur. The traditional nondestructive testing method such as magnetic flux leakage, ultrasonic, eddy current, etc. can only detect the defects that have been developed, while it is powerless to diagnose the early damage of the metal component which is developed by the stress concentration. These regions are often the danger areas of component failure.

The Metal Magnetic Memory Testing Technology

Metal magnetic memory testing technology is a rapid nondestructive testing method to detect the stress concentration location of components by metal magnetic memory effect. It overcomes the shortcomings of traditional nondestructive testing technology. Metal magnetic memory testing technology can stress the stress concentration area of ferromagnetic metal component, so it can diagnose micro defect, early failure and damage. It can prevent sudden fatigue damage, and is a new detection method in nondestructive testing field.

The Basic Principle of Metal Magnetic Memory Testing Technology

In 1997, the Russian scholar Doubov first proposed the Metal Magnetic Memory Testing technology which can be used for early diagnosis of ferromagnetic pipeline [1, 2].

As shown in Fig.1, the basic principle of the Metal Magnetic Memory Testing technology can be expressed as: For the effect of the load, the domain organization orientation will cause magnetostriction properties and irreversible reorientation in the Ferromagnetic components working in a geomagnetic field. The maximum leakage magnetic field is formed in the stress and deformation zone. The tangential component of the magnetic field in the stress concentration area \( H_p(x) \) has the maximum value, while the sign of the normal component \( H_p(y) \) changes and has zero-crossing position [3, 4, 5]. The irreversible change of the magnetic state remains after the elimination of the working load [6, 7]. By the testing of the magnetic flux leakage field’s normal component \( H_p(y) \) and
the calculation of gradient, the stress concentration position of the component can be exactly deduced \[.\]

\[\text{Figure 1. Schematic of Metal Magnetic Memory Testing Technology.}\]

**The Artificial Neural Network**

The Artificial Neural Network (ANN) is a hot research topic in artificial intelligence field since 1980s. It abstracts the human brain neuron network from the point of view of information processing, establishes a simple model, and forms different networks according to different connection modes. In engineering and academia, it is often referred to as neural network directly.

Neural network is an operation model, which is composed of a large number of nodes (or neurons). Each node represents a particular output function, called the activation function. The connection between two nodes represents a weighted value for the connection signal, called the weight, which is equivalent to the memory of the artificial neural network. The output of the network is different according to the connection mode of the network, the weight value and the incentive function. The network itself is usually an approximation of some algorithm or function in nature, or it may be an expression of a logical strategy. In recent more than 10 years, the research work of artificial neural network has been deepened, and great progress has been made. In pattern recognition, intelligent robot, automatic control, prediction, biology, medicine, economics and other fields, it has successfully solved many practical problems, showing good smart properties.

**Experiment**

600 experimental samples were collected. Among them, the sample number of pipeline in good condition is 200, pipeline with Stress concentration is 200, and the pipeline with crack is also 200. The input characteristic matrix of some samples is shown in table 1. the symbol 001 represents this sample is collected from pipeline in good condition. 010 represents this sample is collected from pipeline with Stress concentration, while 100 represents this sample is collected from pipeline with crack.

<table>
<thead>
<tr>
<th>No. of feature vector</th>
<th>Sample category</th>
<th>geometric parameter (mm)</th>
<th>( H_{pp}(A/m) )</th>
<th>( H_{xy}(mm) )</th>
<th>( K_y(A/m/mm) )</th>
<th>( K_x(A/m/mm) )</th>
<th>( W_{10}(mm) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>001</td>
<td>81</td>
<td>151</td>
<td>11.2</td>
<td>10.3</td>
<td>81</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>001</td>
<td>98</td>
<td>119</td>
<td>18.1</td>
<td>14.1</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>010</td>
<td>87</td>
<td>159</td>
<td>14.3</td>
<td>12.3</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>010</td>
<td>44</td>
<td>98</td>
<td>5.1</td>
<td>4.9</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>5</td>
<td>0.1</td>
<td>0.5</td>
<td>45</td>
<td>82</td>
<td>7.5</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>10</td>
<td>0.1</td>
<td>2.3</td>
<td>283</td>
<td>107</td>
<td>23.8</td>
</tr>
</tbody>
</table>
480 samples are used as training samples. The number of samples in each category is 160. The remaining 120 samples are used as test samples. Three neural networks are established for each type of the samples. These three neural networks are labeled as ANN-1, ANN-2, ANN-3 respectively. When the number of hidden layer nodes in neural network is 4, the training error of neural network ANN-1 and ANN-3 is minimum. While, when the number of hidden layer nodes in neural network ANN-2 is 5, the training error of neural network is minimum. In this case, the three neural networks can simultaneously meet the requirements of recognition accuracy and training time. After 3002 cycles, the neural network ANN-1 achieves the training goal, and its training error is 0.0431122. For neural network ANN-2 and ANN-3, their training time and training errors were 3934, 4103, and 0.1109314, 0.0490437, respectively.

Discussion
The classification of the testing samples is correct, except the identification of samples No. 100th, 115th and 127th. The accuracy of sample recognition is 97.5%. This is due to the size of 100th, 115th and 127th samples are 4 x 0.1 x 0.2, 3 x 0.1 x 0.3 and 2 x 0.1 x 0.2 (unit: mm), respectively. These three samples are very small cracks, between the stress concentration and the macroscopic crack. Therefore, their eigenvalues are very similar to those of stress concentration, which leads to identification errors.

Summary
Magnetic memory testing technology is a new nondestructive testing technology, which can be used for early diagnosis of ferromagnetic metal materials. Based on the magnetic memory testing technology, this paper identifies the pipeline defects according to the BP neural network theory. The experimental results show that the magnetic memory testing technology can effectively identify the pipeline defects.

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References