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ANSYS Simulation Model of Buried Metal Pipeline Corrosion Detection

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Abstract: Corrosion testing of buried metal pipelines is an important measure to ensure the safe operation of pipelines. In order to investigate the transient electromagnetic field named response of buried metal pipelines, a three-dimensional simulation model was established by using multiphysics simulation software named ANSYS Multiphysics to calculate and analyze buried metal pipelines with different corrosion degrees, ie different wall thicknesses, on the receiving coil after the excitation signal is turned off[1]. The induced electromotive force changes, the results show that the larger the wall thickness, that is, the smaller the corrosion degree, the slower the attenuation of the induced electromotive force curve of the receiving coil, the smaller the wall thickness, the faster the attenuation; and the verification was experimented: the transient electromagnetic method can effectively detect the degree of corrosion of metal pipes buried under the ground.

1. Introduction

Consumption of petroleum, natural gas, chemical and other products has grown rapidly with the rapid development of the economy, and has promoted the rapid development of the pipeline transportation industry to become the fifth largest transportation industry after road, rail, aviation, and water transportation, making the pipeline widely used in various industries For conveying gas, liquid or fluid with solid particles[2]. Considering the city's beauty, transportation safety and other factors, the pipeline is often buried, so buried pipelines account for a large proportion in the transportation pipeline network. Buried metal pipes are subject to corrosion and perforation due to the long-term influence of the humid environment in the underground soil. Pipe perforations can cause transportation medium leakage, resulting in unpredictable economic losses and even personal injury. For example, oil and gas leaks can easily cause fires and gas leaks Cause an explosion, etc. [1]. So the corrosive detection of buried metal pipelines is of great significance to ensure its safe operation.

The transient electromagnetic method based on the principle of electromagnetic induction is an artificial source time domain electromagnetic method for non-contact signal loading mode[3]. It uses a transmitter to emit a step pulse excitation signal to the ground, and the excitation signal is turned off and then used for reception. The device senses the change induced by the underground medium to induce the secondary field, and through the analysis of the secondary field, extracts effective information related to the detection of the target[4]. The buried pipeline corrosion transient electromagnetic detection method is a relatively novel non-destructive testing method for buried pipelines. Compared with other non-destructive testing methods, it has the advantages of no excavation, in-service inspection, simple and easy to operate, and less affected by the topographic environment. . The forward modeling process as a theoretical basis for transient electromagnetic detection of buried metal pipelines and a basic means for studying transient electromagnetic field response characteristics is extremely important in the study of buried pipeline transient electromagnetic detection: Lijia Wu[5] uses ANAYS limited single-embedded pipeline model with different wall thicknesses of 2D and 3D established by the meta-simulation software. The transient electromagnetic field response of buried metal pipelines with different thicknesses was studied after calculation. The simulation results were verified by experiments. Zhiqiang Yan[6] uses the ANAYS finite element simulation software limited the three-dimensional model of parallel buried pipeline corrosion. The transient electromagnetic response of parallel buried pipelines with different wall thickness and different pipeline spacing was calculated.

In this study, ANSYS was used to establish three-dimensional simulation models of buried metal pipes with different wall thicknesses for solving calculations. The induced secondary fields of metal pipes with different wall thicknesses after the excitation signal was turned off were drawn, and the induced electromotive force attenuation curves of buried pipes were drawn. The ability of transient electromagnetic method to detect different corrosion levels of buried metal pipelines; the simulation results were verified by experimental analysis.

2. Simulation model and analysis of its calculation results

2.1. Design of simulation model

Buried metal pipelines usually show the loss of metal when the corrosion phenomenon occurs, the tube wall becomes thinner, the resistance and conductivity of the pipe body changes, and the thickness of the pipe being tested makes the signal received by the receiver significantly different. Through the extraction and analysis of relevant characteristic signals, it can provide a basis for the qualitative research and analysis of transient electromagnetic buried pipeline corrosion detection [7].

ANSYS software selects nodal-based 3D transient magnetic field analysis, including three parts: pre-processing module, loading and solving module, and post-processing module. The geometric model includes the excitation coil, detection coil, measured pipeline, soil and air. Four materials are set: air, pipeline, coil, and soil. The four material properties are shown in Table 1-1. The calculation range of the whole model is set to a rectangular parallelepiped of 2.4×2.4×6m, the upper part of 0.98×2.4×6m is the air area, and the lower part of the 2.02×2.4×6m is the soil area. The measured pipe size is Φ273×7mm and the length is 3m. The medium inside the pipe is air. The buried depth of the pipeline, that is, the center of the cross section of the pipeline is 1m away from the ground. The excitation coil and the receiving coil are placed horizontally on the ground surface, which is the center loop device, in which the radius of the transmitting coil is 0.22m, the number of turns is 30, and the launching area is $6.4m^2$; the radius of the receiving coil is 0.18m, receiving parameters of 60, receiving area of $5.57m^2$. The excitation signal is applied to the excitation coil, and the effective value of the excitation signal voltage is 12V. When the excitation signal is loaded to 0.0001s, it is turned off and the off time is 50μs. After adding materials, we mesh the model. In the grid option, the mesh is divided into different parts of the model by the user control grid size. Here, the whole model is divided and then the coils and pipes are meshed and meshed. The result of the division is shown in Figure 1. The reliability calculation result can be achieved by controlling the meshing accuracy. After the model mesh is divided, the boundary conditions and loads are applied, as shown in Figure 2, and the time step is set to 1e-4s for calculation and solution.

Table 1. Material Parameter Table

Parameter	Air	Pipe	Coil	Soil
Relative permeability	1	350	1	1
Resistivity(Ω.m)	-	1E-7	3E-8	50

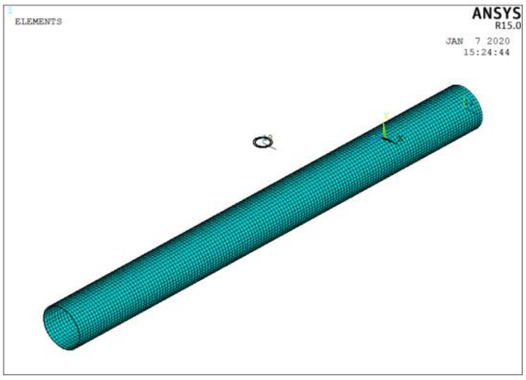


Figure 1. Coil and pipeline grid section

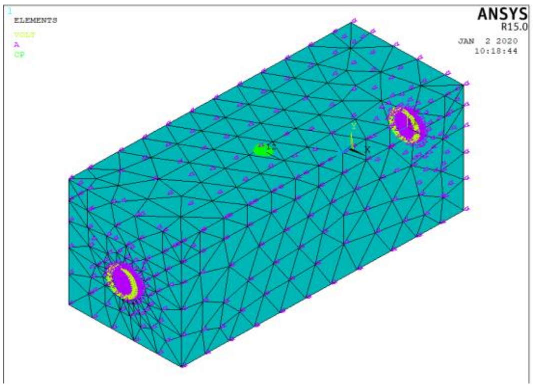


Figure 2. Boundary Condition Model

2.2. Results and discussion

Pipes with different degrees of corrosion have significant differences in transient electromagnetic field responses due to different metal amounts. In order to compare the trend of induced voltage on the pipeline with different degrees of corrosion after the excitation signal is turned off, the buried metal pipeline model with wall thicknesses of 5 and 3 mm is calculated under the same conditions.

After the 3D simulation calculation is completed, the received coil induction voltage list calculated by each model is exported, and then imported into MATLAB to draw the induced voltage curve, As shown in Figure 3 (abscissa is time and ordinate is coil induced voltage), it can be obtained that the amplitude of the transient electromagnetic induction voltage before the excitation signal is turned off in a pipeline with less corrosion, that is, a thicker wall The larger the corrosion degree is, that is, the smaller the wall thickness is, the smaller the amplitude of the transient electromagnetic induction voltage is before the excitation signal is turned off. In order to analyze the difference of the transient electromagnetic response of different wall thicknesses of the pipe, the ordinate of the attenuation curve of the induced voltage in Figure 3 is taken as the natural logarithmic coordinate, as shown in Figure 4 (a). It can be seen from Figure 4 (a) that the three induced voltage decay curves have significant differences in speed at the later stage. Although the induced electromotive force curve of the 7mm-thickness pipe has the largest amplitude when the excitation signal is turned off, the decay rate of the curve is the slowest at the later stage. On the contrary, the induced electromotive force curve of a pipe with a thickness of 3mm has the smallest amplitude when the excitation signal is turned off, but the decay rate of the curve is the slowest at the later stage, and a pipe with a thickness of 5mm also meets this situation. This shows that the greater the degree of corrosion, the greater the amplitude of the transient electromagnetic induction voltage curve before the signal is turned off, and the faster the decay rate in the later period, that is, the corrosion condition of the pipeline can be effectively judged by analyzing the attenuation law of the induced electromotive force curve of the pipeline[8]- [12].

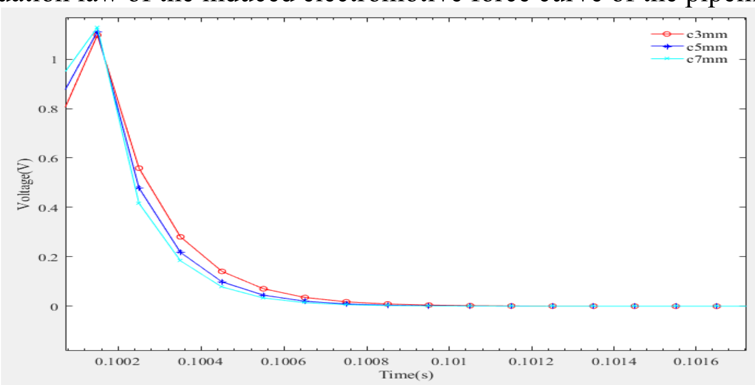
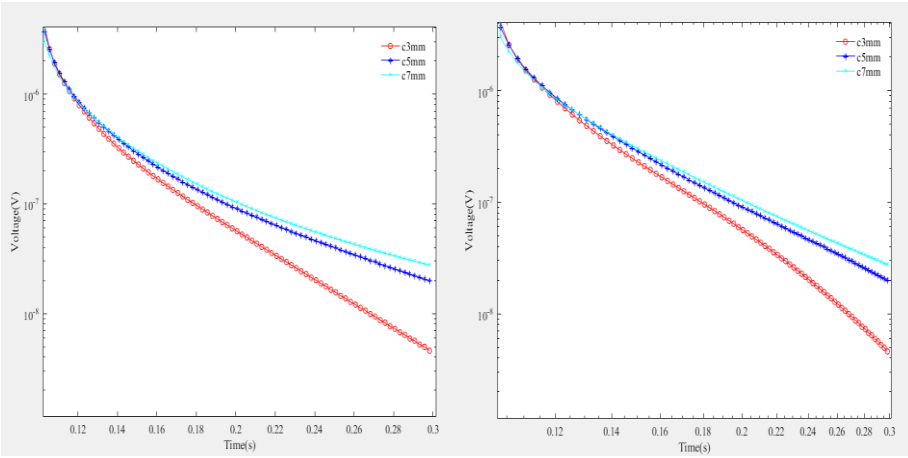


Figure 3. Comparison of Transient Response Amplitudes of Different Wall Thickness Simulations



(a) (b)

Figure 4. Single-log and double-log coordinate system transient response curves

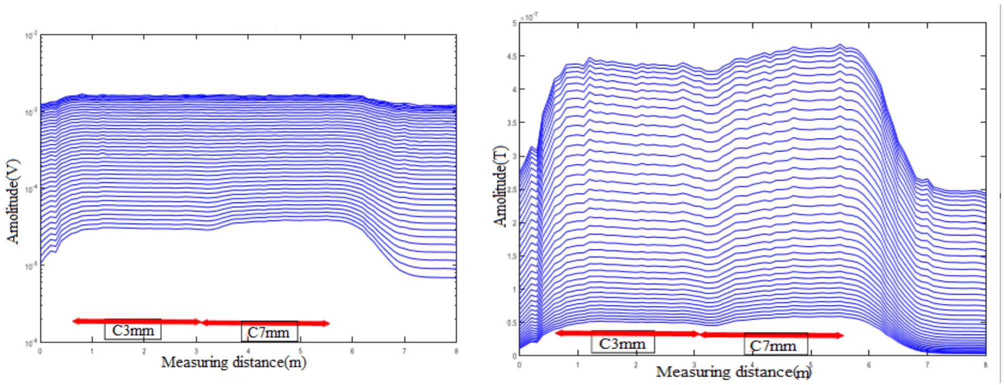
In order to more intuitively reflect the difference in the attenuation speed of the induced voltage curve, the ordinate single logarithmic coordinate system of Fig. 4 is taken as the abscissa double logarithmic coordinate system, as shown in Figure 4 (b). Compared with the single logarithmic coordinate system, the difference of the induced voltage depletion curve in the double logarithmic coordinate system is more obvious in the later period.

3. Experimental analysis

The two steel pipes used in the experiment, one with a length of 3000.0mm, a specification of Φ273 ×7mm, and one with a length of 3000.0mm, a specification of Φ273 × 3mm. The two pipes were connected in series to simulate corrosion. The corrosion depth was 4mm. After the pipe under test is buried, the experiment is performed, as shown in Figure 5: the wall thickness of the rusty pipe is 3mm, and the wall thickness of the stainless steel pipe is 7mm.

Figure 5. Experimental site actual map

The buried depth of the pipeline is 500.mm. The spot measurement method is adopted in the experiment. The measuring points are arranged directly above the pipeline. The spacing between the measuring points is 100.0m. The 3mm pipeline buried point is the first measuring point with a total of 60 measuring points. Through processing the experimental data, the cross-sectional diagrams of the uniform induction electromotive force and the uniform magnetic field of the receiving coil are shown in Figure 6 (a) and (b). It can be seen from the sectional view that the amplitude is small from 0.5m to 3.5m and the attenuation is fast; the amplitude from 3.5m to 6m is large and the attenuation is slow; that is, the pipe with a large wall thickness has a large amplitude and the attenuation is slow; the pipe with a small wall thickness has an amplitude Small, fast decay, the experimental results are consistent with the simulation results.



(a) Profile of uniform induced voltage (b) Uniform magnetic field profile

Figure 6. Transient electromagnetic response of pipeline

4. Conclusion

The simulation and experimental results show that:

(1) After the excitation signal is turned off, the magnetic field strength around the pipe is gradually increased, but with the increase of time, the magnetic field strength on the pipe wall is exponentially attenuated, and the induced electromotive force attenuation curves of different wall thickness pipes are significantly different.

(2) The larger the wall thickness, the greater the amplitude of the induced voltage before the signal is turned off, and the slower the attenuation in the later period. The smaller the wall thickness, that is, the greater the corrosion, the faster the transient response magnetic field decay. The transient electromagnetic method can effectively detect the overall corrosion of the buried metal pipeline.

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