Design and development of safety assessment software for buried pipeline

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Abstract. Professional knowledge and practical experience are required to perform the assessment, and the criteria include a large amount of formulae and tables of data, which are manually calculated at great expense of work and time. To address the above issues, safety assessment software for buried pipelines has been developed, which can be used to assess two typical complex working conditions and four unfavorable conditions. The results show that the software is accurate, intelligent, user friendly and convenient for users.

Keywords: Buried pipeline, Safety assessment, Software

1 Introduction

Safety assessment of buried pipeline is a common demand of users, inspection institutions and regulatory agencies. Professional knowledge and practical experience are required to perform the assessment, and the criteria include a large number of formulas and tables of data, which cost a great deal of work and time by manual calculation. In order to perform the safety assessment of buried pipelines quickly and accurately, it is important to develop relevant standard software and intelligent to improve the level of safety assessment of buried pipelines in China[1-3].

In this paper, by analyzing the formation mechanism of typical complex conditions and unfavorable condition, as well as the load characteristics and failure modes of the pipeline under these special working conditions[4], the mechanical analysis models of the pipeline under two typical complex working conditions of occupation and dent and four unfavorable conditions of goaf, landslide, flood and fault are established. It includes simplified analytical computational methods and sophisticated finite element models to develop application software with engineering utility.

2 Software function module

The software mainly consists of user management, pipeline safety assessment under complex working conditions, pipeline safety assessment under unfavourable condi-

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tions, file and report management and other modules, each of which can be invoked through the main interface of the program, and the modules are interrelated and organically combined. The overall framework diagram of the software is illustrated in Figure 1.

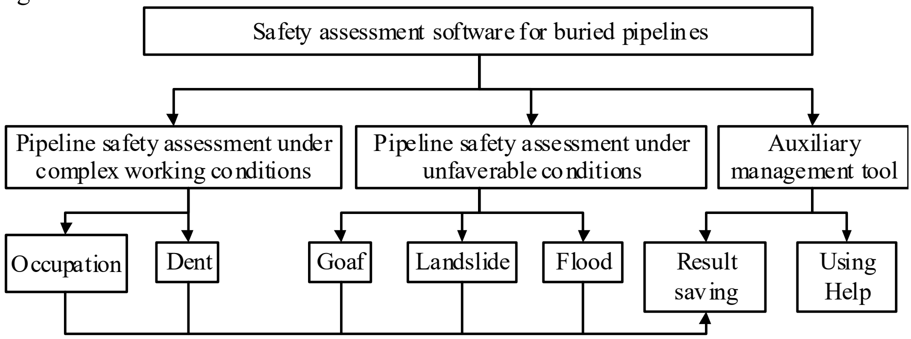


Fig. 1. The framework of safety assessment software for buried pipelines

3 Main module design and technical realization

3.1 Pipeline safety assessment under complex working conditions

3.1.1. Occupation. Under the combined action of the vertical pressure of the overlying soil, the additional stress of the ground load and the support reaction of the foundation at the bottom of the pipe, the cross section of the pipe may appear ellipticity, that is, the uneven radial deformation of the pipe wall. This module uses the national standards GB50253-2003 and GB50332-2002 to calculate the vertical soil load and the vertical soil pressure at the top of the pipe, respectively. The additional load is calculated using the diffusion angle method and the Boussinesq method[5,6].

This module establishes a three-dimensional finite element model of the pipeline and its surrounding soil under the action of occupation. The interaction between the pipe and the soil is taken into account by the model, and pipeline is treated as a shell. This module provides a more comprehensive simulation of the pressure situation in the pipeline, and the analytical results are reliable and accurate. The flow chart of occupation pipeline safety assessment is illustrated in Figure 2.

3.1.2 Dent. At present, magnetic flux leakage (MFL) internal inspection technology is most widely used to obtain the dent data, but due to the limitation of accuracy, the detection data is difficult to accurately reflect the contour of the dent, and the curvature of the dent is difficult to determine. The module uses cubic spline interpolation method to compute the circumferential and axial contours of the dent, and the strain evaluation method in ASME B31.8 is used to calculate the maximum strain of the dent[7].

3.2 Pipeline safety assessment under unfavorable conditions

3.2.1. Goaf. The module uses a probabilistic integration approach to predict the ground deformation and is able to predict the horizontal and subsidence displacements at the point of impact, the dip in the main section and at any location above the goaf. If the buried pipeline can be exactly matched to the surface settling deformation, then the pipeline deformation can be represented by the surface deformation curve. Based on the elastic foundation beam theory, the flexible pipeline criterion is established and the critical diameter of pipeline is obtained as a function of the performance parameters of the pipeline structure, the soil properties of the site and the target parameters.

3.2.2. Landslide. In the case of longitudinal landslide, the direction of pipeline is parallel to the direction of landslide flow, assuming that all soil layers on the slope slide at the same time, the pipeline is subject to the axial action of landslide soil mass and the gravity component of the pipeline itself, and the cross section of the pipeline at both ends of the landslide body is also subject to the action of internal axial force. According to the equilibrium equation of the axial force of the whole section of the pipeline in the landslide area, the internal force of the pipeline can be solved, and the axial strain of the pipeline can be obtained by substituting Ramberg-Osgood constitutive equation[8,9].

When a lateral landslide occurs, the pipeline bends and deforms due to the lateral drag of the slope body and its own gravity along the slope body. Assuming that the pipe is uniformly stressed and not damaged, the maximum bending of the pipe occur when the transverse action between the pipe bodies reaches the limit value.

The nature of the landslide soil mass is complicated, as is its effect on the pipeline. When the scale of the transverse landslide is large, it may cause local buckling of the pipeline at the landslide edge, which has also occurred in past pipeline accidents. In this module, three-dimensional shell elements are used to build a finite element model of the lateral landslide.

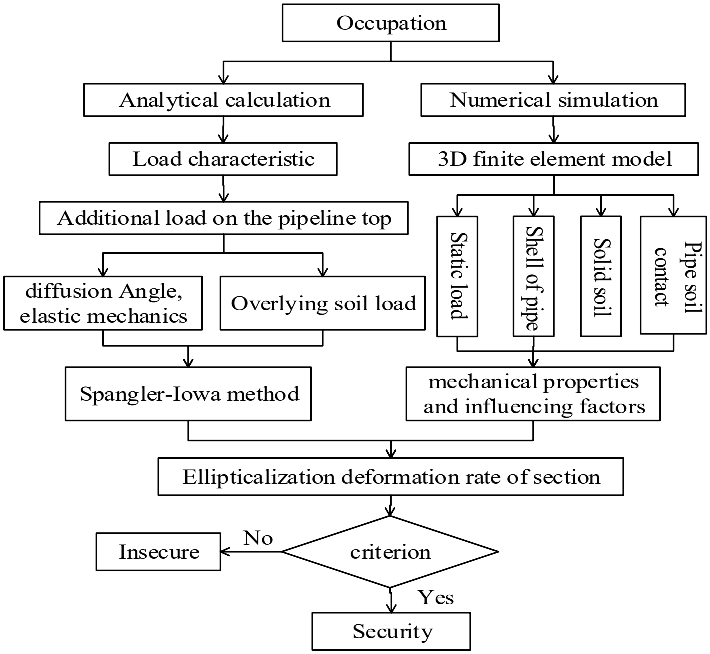


Fig. 2. The flow chart of occupation pipeline safety assessment

3.2.3. Flood. Assuming a uniform flow and a fixed flow rate, the section of the floating pipe is subject to the drag force of the flow, the vertical lift force, the gravitational force, and the buoyancy force, where the drag and lift forces are calculated according to the Morrison equation. At the same time, the buried pipes on either sides of the embankment were subjected to the soil resistance in both directions[10].

According to the direction of action, the load on the floating pipeline is divided into two categories: one is the horizontal direction (along the flow rate direction) of the water drag force, and the other is the vertical direction of the buoyancy, lifting force and gravity (pipeline and conveying medium). The flow chart of flood drifts pipeline safety assessment is illustrated in Figure 3.

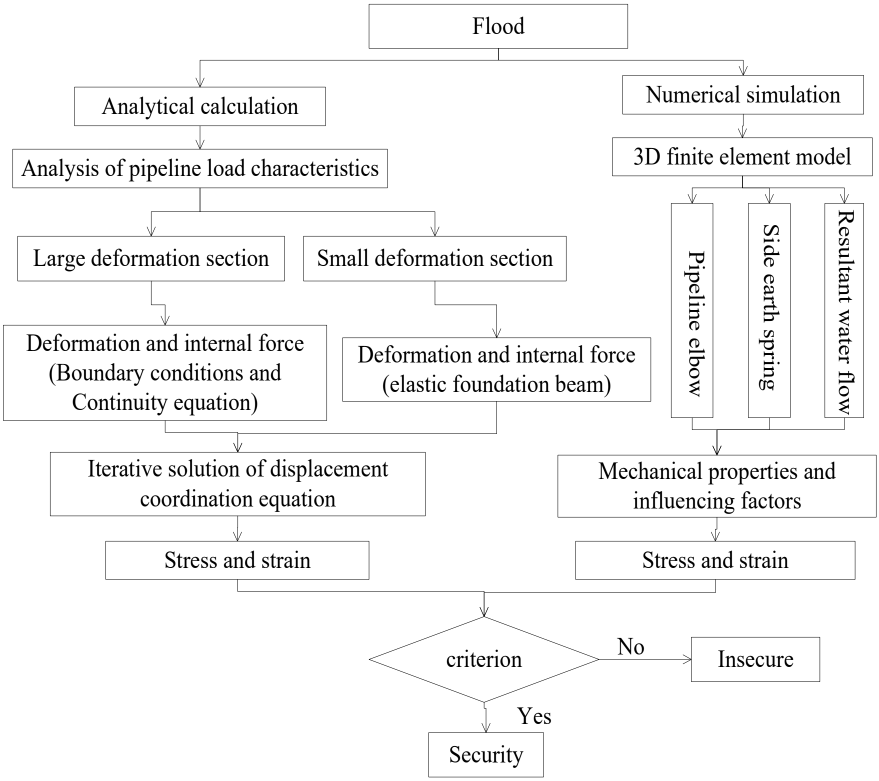
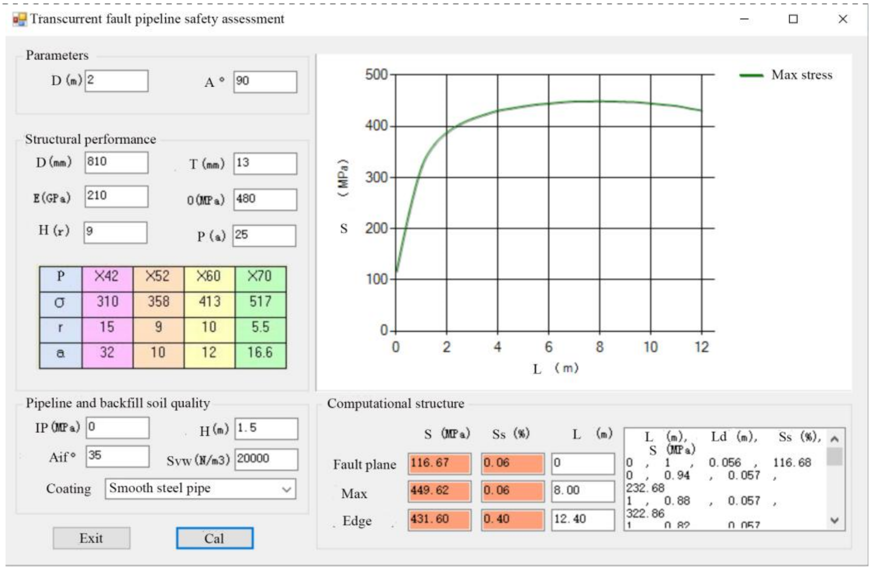


Fig. 3. The flow chart of flood drifts pipeline safety assessment

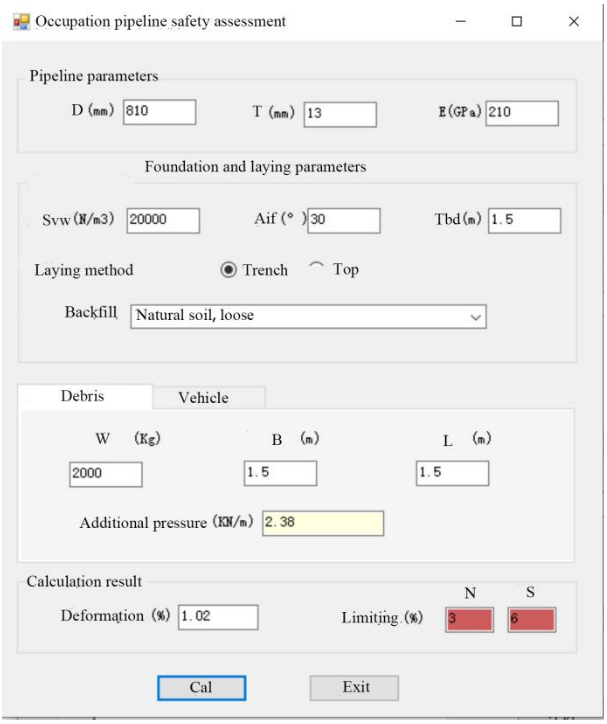
4 Application

A gas enterprise pipeline was selected for evaluation, which included big data collection of the pipeline, ambient investigation, high-consequence area identification, risk assessment, integrity evaluation and other work.

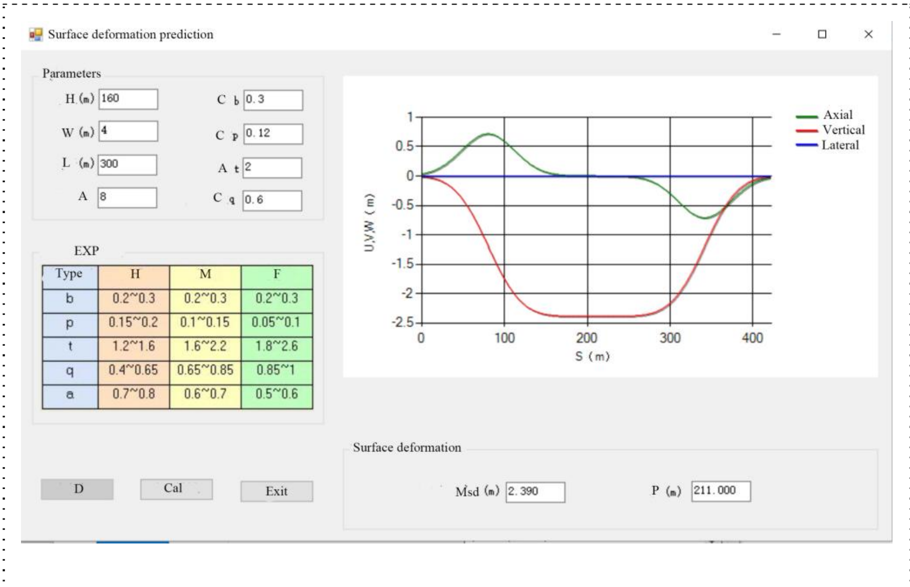
The results of the security assessment of the pipeline with this software are shown in figure 4.



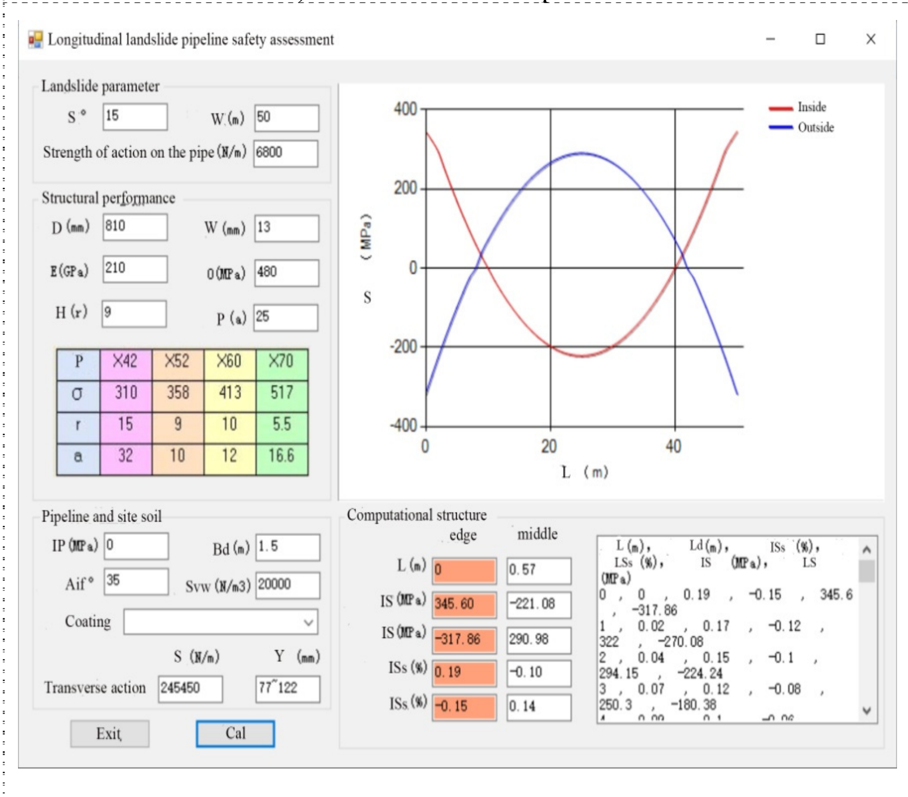
a) Transcurrent fault pipeline safety assessment



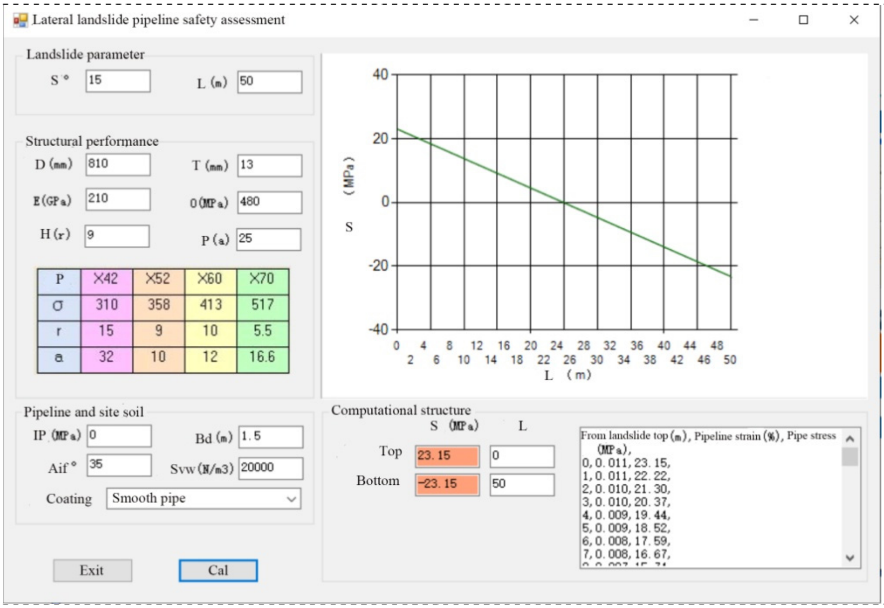
b) Occupation pipeline safety assessment



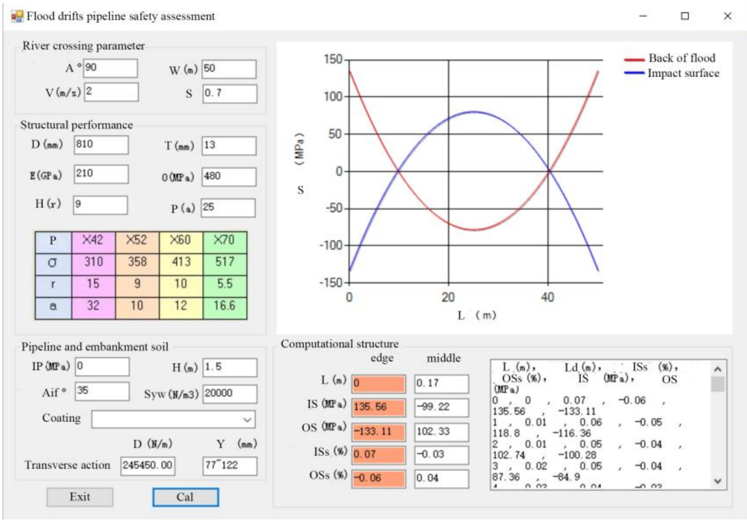
c) Surface deformation prediction



d) Longitudinal landslide pipeline safety assessment



e) Lateral landslide pipeline safety assessment



f) Flood drifts pipeline safety assessment

Fig. 4. Pipeline safety assessment

The above results have very positive implications for predicting the consequences of pipeline accidents, formulating protective measures, reducing disaster losses, and ensuring pipeline safety.

5 Conclusion

Evaluating pipeline safety with this software is fast, convenient and accurate. Most of the work that requires manual computation is done by computer, which greatly reduces the time required for evaluation.

In the next step, the mobile line patrol app and hidden danger management module will be added to the software. Tracking management will be carried out for third-party construction management and hidden danger (landslide, leakage, occupied pressure) found during line patrol, and line patrol personnel will use mobile phone app to collect, upload and report data in real time.

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