Study on the Pipeline Fragility Appraisal Indicators Affected by landslide Based on Numerical Simulation

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Abstract. The completeness of pipelines is tremendous influenced by landslide in unfavorable geological conditions. The quantifying appraisal techniques is a valid means for risk management of pipelines affected by geological disasters. By using the finite element method to simulate going steadily downhill, mechanics characteristic of pipeline and pipe/soil interaction with changes in physical dimension consisted of the landslide area (LA), landslide thickness (LT), pipeline length in landslide (PLL), calibre (CA) and wall thickness (WT) of pipeline, the fragility appraisal system of pipeline affected by landslide can be constructed. The regular pattern of stress and strain variation of pipeline affected by landslide can be acquired with number analysis and computation. The results show that the physical dimension of landslide and the PLL have strong effect on pipeline fragility, and the effect increases with increasing of the above indicators; the WT has a smaller role of pipeline fragility and the effect can be ignored. In the end, the weighting factors and marks of every fragility appraisal indicator can be given on the basis of the above conclusion.

1. Introduction
The long-distance pipeline is an important lifeblood of national economy. The vast geographical area leads to complex and changeable geological conditions along the pipeline. In addition, human construction and production activities are becoming more frequent, which further exacerbates the susceptibility of geological disasters. The geomorphological conditions along the pipelines in the mountainous areas of southwestern China are complicated, with heavy annual rainfall and frequent heavy rainfall, and frequent geological disasters [1-3]. Landslide is one of the typical pipeline geological disasters, and it is a natural evolution phenomenon that the slope tends to stress equilibrium under the action of gravity. Mountain pipelines are prone to bending deformation and even fracture when encountering landslide disasters, resulting in serious consequences. Therefore, it is particularly important to study pipeline landslides. Many scholars have done a lot of work on its monitoring and risk assessment [4-6]. In order to avoid the hazards caused by landslide disasters to the pipeline, in the pipeline design process, it is often used to avoid existing or potential landslides, but due to various factors, some pipelines have to pass through existing or potential sliding areas. During the pipeline construction process, landslides may be formed due to the disturbance of the pipeline construction to the mountain; during the pipeline operation process, new landslides may also be formed due to earthquakes, rainfall or human factors. From the above analysis, we can see that the landslide disaster is a geological disaster that cannot be avoided for safe pipeline operation [7-8]. In view of the
unavoidable nature of pipeline landslide disasters, the seriousness of the consequences of pipeline accidents caused by landslides and the danger of pipeline media, from the perspective of maintaining pipeline safe operation and protecting people’s lives and property from damage, it is necessary to conduct pipeline landslide disaster risk assessment the study.

2. Numerical procedures

2.1. numerical modeling
The model is 118m long along the strike, 85m long along the tendency, and the leading edge is 17m, the trailing edge is 32m. the dip angle of mountain is 32 degree, the pipeline depth of embedment is 1.75m. The reference surface of model is constrained in three directions, and the profiles are controlled by the method of normal displacement. Every numerical procedure has different physical dimension and calculation parameters for the landslide and pipeline. As is shown in figure 1. The pipeline passes through the leading edge of the landslide. During the simulation, the elastic model is used for the pipeline, while the Mohr-Coulomb one for the soil mass [4].

![Figure 1. Numerical model of pipeline in landslide.](image)

In order to obtain the physical and mechanical parameters of rock and soil materials, the original samples were taken out by machines at the engineering site, and the original samples were tested for density, compressive strength, shear strength and tensile strength. The mechanical performance indexes of grade X70 pipeline steel can be obtained according to querying related standards and mechanics manuals. The parameter values discussed above are summarized in table 1.

| Parameters categories | $E$(GPa) | $\mu$ | $\gamma$(kN/m$^3$) |
|-----------------------|---------|-------|------------------|
| pedestal rock         | 41.2    | 0.25  | 3150             |
| slide body            | 3.32    | 0.34  | 2150             |
| glide plane            | 0.10    | 0.43  | 1600             |
| Pipeline steel        | 205     | 0.28  | 8200             |

Where, E, $\mu$ and $\gamma$ are the elastic modulus, passion’ ratio and volume-weight.

2.2. schematic design
In order to fully consider the changes of the fragility appraisal indicators of pipeline affected by going steadily downhill under different working conditions, we have designed 5 different calculation schemes for the numerical simulation according to 5 key parameters, the pipeline length in landslide ($PLL$), landslide area ($LA$), landslide thickness ($LT$), calibre ($CA$) and wall thickness ($WT$) of pipeline. There are 7 different types of calculation conditions aiming at every key parameters presented in the table 2.
Table 2. The calculation conditions for the numerical simulation according to 5 key parameters.

| No. | PLL (m) | LA (m²) | LT (m) | CA (mm) | WT (mm) |
|-----|---------|---------|--------|---------|---------|
| 1   | 3.0     | 100     | 2.8    | 320     | 5.0     |
| 2   | 5.0     | 200     | 4.0    | 387     | 6.0     |
| 3   | 10.0    | 400     | 6.5    | 435     | 7.0     |
| 4   | 15.0    | 600     | 8.0    | 512     | 8.0     |
| 5   | 20.0    | 800     | 12.0   | 620     | 9.0     |
| 6   | 25.0    | 1000    | 15.0   | 740     | 10.0    |
| 7   | 30.0    | 1200    | 17.5   | 1220    | 12.0    |

3. Result Analysis

The ANSYS software is applied to conduct the simulation study. As can be seen from the FEM analysis nephogram of displacement field shown in the figure 2, the increase of PLL can result in the increase of both the pipe stress and maximum displacement, including 3 different types of calculation conditions that PLL is 10m, 20m and 30m.
PLL=30m

Figure 2. FEM analysis nephogram of displacement field.

Analogously, the numerical procedure according to the parameters $LA$, $LT$, $CA$ and $WT$ are conducted. As can be seen from the figure 3, the increase of $LT$ can result in the increase of both pipe stress and displacement, and there is a large increase in both the stress curve and the displacement curve when the value of $LT$ reaches 8.0m.

Figure 3. The trend chart of pipe stress and displacement along with $LT$.

Figure 4 and 5 are the maximum values of pipe stress and displacement under 5 different types of indicators.
Figure 4. The maximum values of pipe displacement under 5 different types of indicators.

Figure 5. The maximum values of pipe stress under 5 different types of indicators.

4. Conclusion
The degree of influence of each calculation scheme on the simulation results varies according to the 5 key parameters. The pipeline length in landslide (PLL), landslide area (LA) and landslide thickness (LT) 3 indicators have a significant impact on the fragility appraisal of pipeline, and there is no obvious convergence in the maximum values of pipe stress and displacement, which means the above 3 indicators will have a lasting impact on pipeline fragility along with their own increasing. The effects of calibre (CA) and wall thickness (WT) of pipeline on the fragility appraisal of pipeline are not obvious compared with first three indicators of physical dimension of landslide, thus the influence of indicators of physical dimension of pipeline on calculation results is negligible.

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