油气管道完整性评价与管理软件*

帅 健　党文义　卜 文平
(中国石油大学· 北京)

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摘　要　作为保障油气管道安全运行的重大举措, 管道的完整性管理已经受到了国内外油气管道业界的高度重视, 并处在不断地推广应用之中。为方便管道完整性管理技术的实际应用, 研制开发了适用于工程实用目的的油气管道完整性评价与管理软件(PIAMS), 并包含了管道风险评价与剩余强度评价的功能模块。为此, 介绍了该软件的结构、模块、特点、主要功能和用户界面; 该软件由数据库、管道风险分析、腐蚀缺陷评价、用户管理 4 个模块组成; 可以运用该软件管理油气管道的完整性数据信息, 进行管道的风险计算、风险分析以及对含缺陷管道的剩余强度评价; 此外, 该软件还具有可扩展性强的特点。

主题词　油气管道　完整性　管理　评价　软件　数据库　风险分析　剩余强度

对管道完整性评价的完整解决方法就是要发展一个以整体风险为基础的决策过程[1], 它包括一整套工具和方法用来储存和保持管道及附属设备、事故频率、后果模型、决策模型以及反馈措施的大量数据资料。为此, 笔者开发研制了适用于工程实用目的的油气管道完整性评价与管理软件。该软件能够管理涉及管道完整性各个方面的大量数据, 并采用先进的理论和方法实现管道的剩余强度和风险评价功能。

一、软件的总体结构

管道完整性评价和管理软件的总体结构见图 1。

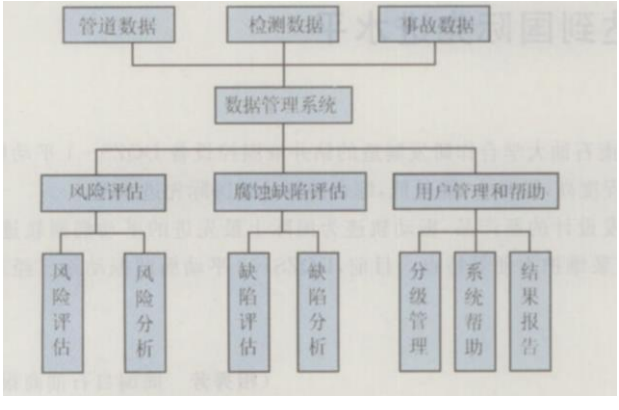

图 1　管道完整性评价与管理软件的设计框图

整个软件由数据库管理、腐蚀缺陷分析评估管道风险评估和分析、用户管理系统和帮助等 4 个模块组成, 每个模块又分为若干子模块。这些模块综合了管道完整性评价所涉及的基本内容。

二、软件的基本功能

(1)数据库和数据处理模块: 快速的数据输入、编辑、查询、统计; 模板数据库结构; 动态分段模型; 用户分级管理。

(2)缺陷评价模块: 确定并报告管道的缺陷序列; 用工业标准方法评估。

(3)风险评价模块: 管线的 MAOP 计算; 失效风险 ROF 和失效后果 COF 模型; 因素权重的调整; 风险值的计算; 风险敏感因素分析; 风险频数统计和特性曲线分布假设检验。

(4)报告模块: 报告风险排序的结果(表格、图表、报表); 报告缺陷评价的结果(表格、图表、报表); 软件的帮助系统。

三、数据库设计

管道完整性评价必须有充分的相关数据来源支持, 因而数据库的设计是本软件的重点。根据管道的特点, 管道完整性所涉及的数据中有基本不变数

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作者简介: 帅健, 1963 年生, 博士, 教授, 博士生导师; 1982 年毕业于武汉化工学院, 现在中国石油大学(北京)从事工程力学和油气储运系统安全工程的科研与教学工作。地址: (102200) 北京市昌平区中国石油大学机电学院。电话: (010) 89733772。E mail: shuaij@cup.edu.cn

据和变化数据之分。管道埋地、穿跨越情况、穿过不同地域的海拔高差、泵站位置和管线的设计数据属于不变的数据。管道的腐蚀检测数据，土壤腐蚀性、管道的运行数据、管道的分段情况，管道周围的人口、财产等属于可变数据，用户应根据实际情况，适时更改数据库中的可变数据。

管道完整性评价与管理软件的通用性，需要建立管道完整性评价数据库模板，对于新加入的管线，通过基本数据库模板来建立新管线完整性评价数据库的基本框架。数据库模板主要包括的数据表如：管线表，管线的分段基本信息表，泄漏历史表，管线的纵断面数据表，穿跨越、套管、固定墩以及其他管道部件数据表，管线的运行压力数据表，AC /DC 数据表，管线的腐蚀缺陷检测数据表，土壤腐蚀性表、阴极保护数据表，第三方破坏数据表，基础移动数据等。图 2 是部分腐蚀数据的关系示意图。为了管道完整性评价操作上的方便，数据库中还储存了缺陷评价和风险评价的中间过程和结果数据。此外，考虑到软件操作需要快速的数据输入、查询和定位，采用了表格集中输入方式，并有方便的添加、删除功能。

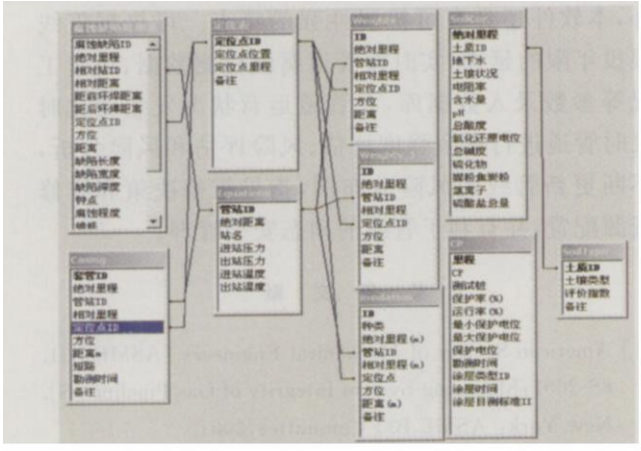

图 2　管道数据关系图

数据库中管段基本表为关键表。这是因为整条管道的长度上没有相同的危害性倾向，在用该软件对管道进行风险评估时，必须对管道分段，管段的划分甚至能决定风险评估的结果和精度，当管线的管段发生改变时，则需要用户重新评估，以便更新管线的风险图。

四、腐蚀缺陷评估

管道腐蚀缺陷评价模块以笔者以前开发的油气管道安全评价软件为基础，并融合了笔者在腐蚀缺陷管道剩余强度评价和剩余寿命预测方面的研究成果[2-5]。

腐蚀缺陷分析是按腐蚀缺陷基本类型、腐蚀程度等级、所在管线轴向和周向部位，用直观的方法进行管线不同区段腐蚀缺陷分布密度的分析，以便在进行腐蚀管线的缺陷评估时调用和对该管段进行风险的腐蚀分析时给评估者提供参考。

腐蚀缺陷评估主要对体积型腐蚀缺陷的剩余强度进行评估。采用 ASME B31G-1991 来评价腐蚀管线的剩余强度，也可采用 DNV RF101 等其他方法。图 3 为管线剩余强度评价流程图。在腐蚀缺陷评价界面上，表格中绿色表示该缺陷已经维修，而红色表示该缺陷为极度危险的缺陷，应该进行维修。

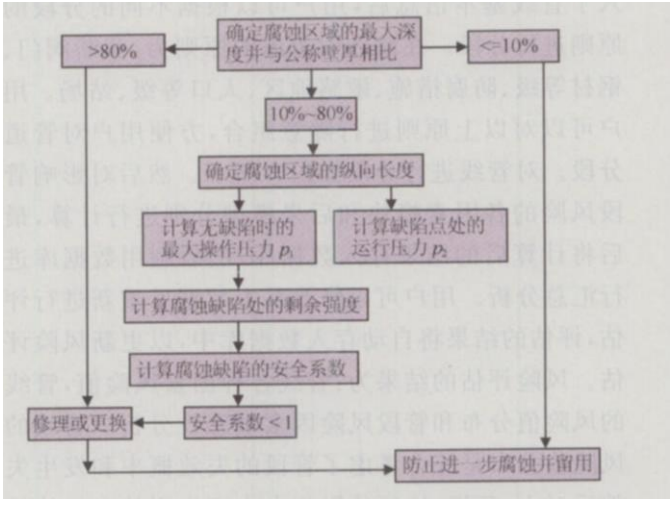

图 3　含缺陷管道剩余强度评价流程图

图 4 为腐蚀缺陷安全系数图，在蓝色线以下的管线部位有极度危险的缺陷。

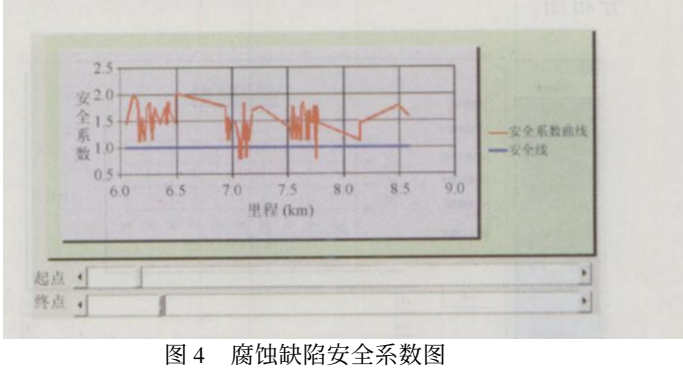

图 4　腐蚀缺陷安全系数图

五、管道风险评估

对于管道风险评估，最根本的是它能对整个管道系统，特别是那些高后果和高事故率区域进行分

析，并利用风险分析结果选择合适的风险降低方案。而且，作为分析过程的一部分，风险评估应根据管道沿线状况的变化，对整个管道系统的分段做出相应的调整，这就需要作大量的反复计算。因此，对于整个管道系统，风险评估本身就需要大量的信息和自动分析的能力。

风险评价模块，能根据管道沿线的地理、人口、环境和管道本身的设计运行参数，得到管线的风险分布图，指出高失效区域和高冲击区域，使管理者了解管线运营的重点风险监测区段，避险的主要行为方式，为管道预知性维护管理，资金的投入和重点维护对象提供一种参考[6]。

在进行管道风险评估前，首先应该输入管线评估所需要的基本数据，然后对管线进行分段。当输入了管线基本信息后，用户可以根据不同的分段的原则进行分段。在软件中考虑的原则为：截断阀门、钢材等级、防腐措施、敏感地区、人口等级、站场。用户可以对以上原则进行随意组合，方便用户对管道分段。对管线进行分段如图 5 所示。然后对影响管段风险的各因素模块和后果模型分别进行计算，最后将计算后的结果存入数据库，然后利用数据库进行汇总分析。用户可以修改基本数据后重新进行评估，评估的结果将自动存入数据库中，以更新风险评估。风险评估的结果为：管线各种因素风险值，管线的风险值分布和管段风险因素敏感性分析。管线的风险值分布是综合考虑了管段的失效概率和发生失效后对人、环境、地区的影响大小而得到的表示管线失效性和危害性的一个综合指标；管段的风险因素敏感性分析是将各因素的评估值与算法中的基准进行比较，而为消减风险提供参考。图 6 为管道风险分布图。

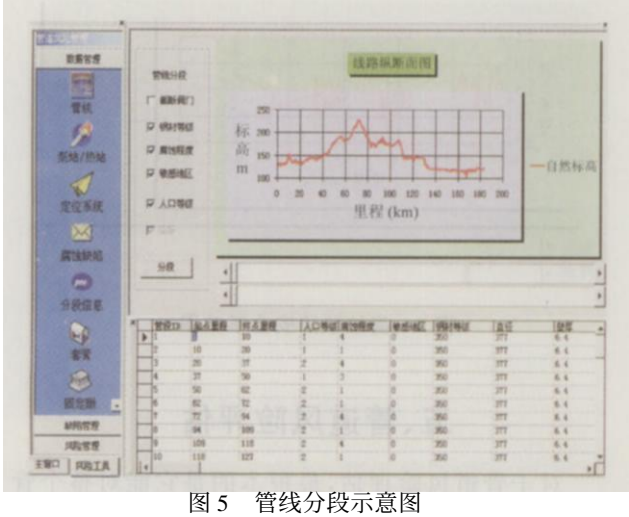

图 5　管线分段示意图

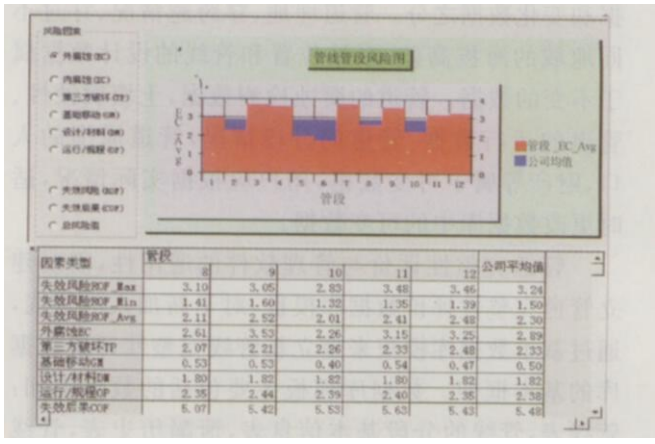

图 6　管道风险分布图

因为对于管线系统，可以假设大部分管线的失效风险值 ROF 分布服从正态分布，而总风险即可能服从正态分布，也可能服从对数正态分布(可能的原因是人口等级、敏感地区对总风险影响很大)。因此在软件中，可以对 ROF 进行频数统计，以方便对 ROF 的假设检验。

此次开发的油气管道完整性评价与管理软件，除为管道的完整性管理设计了数据库之外，还开发了管道风险评价与剩余强度评价的功能模块。此外，本软件还具有可扩展性强的特点。可根据管线服役年限的延伸，实时将管道腐蚀检测数据、运营工况等参数录入数据库，在管道运营状况发生变化时及时管道进行剩余强度评估、风险评估和风险分析，不断更新管线的风险分布图，指导维修决策和维修资源配置，并有利于管线的动态安全管理。

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1000 – 0976; **In Chinese**)

ABSTRACT: The borehole temperature distribution is the necessary parameter for design and performance analysis of gas wells, which can be obtained by direct measurement or calculation. But, it is difficult for the super deep wells, the gas wells with high temperature and pressure and the gas wells with complicated state to measure directly. As for the gas wells with high gas/liquid ratio, the calculating method of borehole temperature distribution has low accuracy and feasibility. So, it is necessary to study the borehole temperature distribution. Based on the heat transferring principle and the bi phase flow theory, the calculating model of borehole temperature distribution for the gas wells with high gas/liquid ratio is established. According to the influence of liquid phase on the thermal parameters, the borehole temperature distribution of the gas well can be calculated even without the well head data. The sensitivity of well head temperature is investigated. The influence of gas production, liquid production, different liquids and tubing diameter on the well head temperature is analyzed. With real case calculating, the calculating average error of well head temperature is 2.35%. Comparing with the results without considering the influence of liquid phase, the calculating results are more fitting to the values of real measurement and more accurate.

SUBJECT HEADINGS: gas /liquid ratio, bi phase flow, borehole temperature, calculation

Xue Xiumin, born in 1978, is engaged in the research on the theory and system of oil/gas field development.

Add: Oil Recovery Technology Institute of PetroChina Dagang Oilfield Company, Dagang District, Tianjin 300280, P. R. China

Tel: 86 10 8973 3152 **E mail**: xiuminxue_2002@163.com

STATUS OF RESEARCH ON NANO LIQUID DISPLACING OIL TECHNOLOGY

Gong Jun, Xu Wenbo, Tao Honghui (PetroChina Daqing Oilfield Limited Company). *NATUR. GAS IND*. v. 26, no. 5, pp. 105-107, 05/25/2006. (ISSN 1000 – 0976; **In Chinese**)

ABSTRACT: Nano technology involves materials with one dimensional size of particle at least in the range of 0.1 to 100 nm and obtaining very special properties just because of the variation of particle size. It includes preparation of nano materials, description of its properties and application. Nano fluid is a solution that consists of nano liquid droplets formed by nano composite materials dispersing in water. Nano fluid is mainly used as an oil displacement agent in oil production to further enhance oil recovery factor. This paper mainly introduces the implication on oil recovery, mechanism and status of nano fluid.

SUBJECT HEADINGS: nano fluid, recovery factor, permeability, low permeability oilfield

Gong Jun (technician), graduated in 2002 from Daqing Petroleum Institute.

Add: No. 4 Oil Production Plant, PetroChina Daqing Oilfield Limited Company, Daqing City, Heilongjiang Province 163000, P. R. China

Tel: 86 459 5680 603 **Cell phone**: 13089006628 **E mail**: gongxutao007@126.com

SOFTWARE FOR INTEGRALITY ASSESSMENT AND MANAGEMENT OF OIL AND GAS PIPELINE

Shuai Jian, Dang Wenyi, Bu Wenping (China University of Petroleum · Beijing). *NATUR. GAS IND*. v. 26, no. 5, pp. 108-110, 05/25/2006. (ISSN 1000 – 0976; **In Chinese**)

ABSTRACT: As one of the substantial solutions to ensure secure operation of oil and gas pipelines, integrality management has been widely highlighted and applied by global oil and gas pipeline industry. To facilitate the application of the pipeline integrality management technology, PIAMS, a kind of software for oil and gas pipeline integrality assessment and appraisal, was specially designed for practical engineering application. Function models for pipeline risk assessment and residual strength appraisal were incorporated in the software. The structure, model, characteristic, main function and user interface of the software are detailed here. PIAMS consists of 4 models, including database, pipeline risk analysis, corrosion defection appraisal and user management. The software can be used to manage the integrated data of oil and gas pipeline, conduct risk calculation and analysis and residual assessment of defected pipelines. Besides, the software was designed with strong expansibility.

SUBJECT HEADINGS: oil and gas pipeline, integrality, management, assessment, software, database, risk analysis, residual strength

Shuai Jian (professor), graduated from Wuhan Institute of Technology. He holds a Ph. D degree and now is working at China University of Petroleum on engineering mechanics, and research and teaching works of storage and transportation system security engineering.

Add: Electromechanical Engineering School, China University of Petroleum, Changping District, Beijing 102200, P. R. China
Tel: 86 10 8973 3772 **E mail:** shuaij@cup. edu. cn

QUANTITATIVE RISK ASSESSMENT ON GAS TRANSMISSION STATION WITH API 581

Gu Zhiyu[1], Shuai Jian[1], Dong Shaohua[2] ([1] China University of Petroleum · Beijing; [2] Beijing Huayou Natural Gas Co. Ltd.). *NATUR. GAS IND.* v. 26, no. 5, pp. 111-114, 05/25/2006. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: Currently, risk assessment method specially designed for gas transmission station is shortfall. The existent method can only get qualitative result from related state laws and regulations, and then modify it to get revamped proposal. Therefore, a new method for quantitative risk assessment of gas transmission station was raised to acquire quantitative and objective hazard sequence, which will provide fully support to integrality management works of pipeline stations. Yulin gas compressor station on the Shaanxi Beijing gas transmission pipeline is taken as an example to perform risk assessment on the facilities by using American Petroleum Institute Standard 581 (API Std. 581, risk based inspection base resource document). The risk value can be acquired by calculating failure effect and ratio of the installments and pipelines in the station. Then further study has been carried out on the reasons why differences of hazard value incur. Finally, opinions and suggestions on risk assessment works of Chinese gas transmission pipelines are presented.

SUBJECT HEADINGS: American Petroleum Institute (API), foreign standard, Shaanxi Beijing Natural Gas Transmission Line, gas transmission station, quantitative, risk assessment, application, suggestion

Gu Zhiyu, born in 1981, holds an M. Sc. degree and now is studying on security engineering of oil and gas storage and transportation system.

Add: P. O. Box 225, China University of Petroleum, Changping District, Beijing 102249, P. R. China
Cell phone: 13811419059 **E mail:** petergu_2001@hotmail. com

EMERGENCY AID SYSTEM AND INFORMATION TECHNOLOGY FOR NATURAL GAS PIPELINE

Xie Anjun (Wenzhou University). *NATUR. GAS IND.* v. 26, no. 5, pp. 115-117, 05/25/2006. (ISSN 1000-0976; **In Chinese**)

ABSTRACT: Emergency management system for contingency is one of the most essential and substantial part of state modern management system, with its core of developing organization capability, and ability to work resourcefully and carefully upon contingencies. Long distance natural gas pipelines are operated under high pressure, so pipeline operation security takes precedence of any other considerations. It's imperative to establish emergency aid system for Chinese natural gas industry, for fear of explosion and gas leak along gas pipeline, which can further cause fire extension and a series of explosions, etc. The emergency aid system can start up a set of integrated corresponding solutions and information technologies, to cut off the gas sources, extinguish fires, allocate rescue resources, rush to repair the damaged facilities, provide medical cares, etc., aiming at minimizing the loss. The main information technologies incorporated in the emergency aid system include: supervisory control and data acquisition system (SCADA), global information system (GIS), global positioning system (GPS).

SUBJECT HEADINGS: natural gas, pipeline, contingency, emergency aid, pre proposal, supervisory control and data acquisition system (SCADA), global information system (GIS), global positioning system (GPS)

Xie Anjun is head of information technology education department of Wenzhou University. He is also a professorial senior engineer in computer science engineering, meantime he is a state registered supervision engineer, first class project account supervisor and executive senior consultant.

Add: Wenzhou University, East Xueyuan Road, Wenzhou City, Zhejiang Province 325027, P. R. China
Cell phone: 13575440255 **E mail:** jsj_xaj@wznc. zj. cn