REVIEW OF LITERATURE ON STRESS ANALYSIS OF PIPELINES

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Abstract: Pipes carrying various fluids are major structural element for every industry. Industries have been facing many problems including failures in the maintenance of pipelines. These problems as well as failures may have been occurred due to excavation, natural forces, material failure, weldment failure, equipment failure, corrosion, improper operations etc. However the main reason for most of the failures is due to lack of withstanding strength required for the pipe. Good amount of research has been made in the field of pipeline design especially in the area of stress analysis of pipelines by various researchers on design, manufacturing techniques and their sustainability under various operating conditions, but still not answered many of the ground situations. The Reliance Gas Transportation Infrastructure Limited is a Company which is transferring natural gas from Andhra Pradesh state to Gujarat state through gas pipeline named as East-West Gas Pipeline is observed to be a right area for making total analysis and to identify probable strength and resistance parameters for their sustainability. It is observed that there were no failures observed in this East-West Gas pipeline in last nine years. So it is the right area for study such pipeline and look for the possibilities of failure that may occur in future, also there is need to observe the necessary preventive measures been followed to avoid disasters. In this paper various case studies and experimental studies conducted by various novel researchers on the stress analysis of these pipelines are studied, comprehended and reviewed which will be a basis for providing better solutions and to provide utmost safety to the said pipeline. This further gives a brief idea of how the problems have been occurred and the possibility of preventive measures taken by the research in maintaining such a large pipeline without any kind of failure of any mode. This review will be helpful in providing sophisticated solution through computerised analysis.

Index Terms - Stress, pipelines, analysis, design, and resistance.

I. INTRODUCTION

Pipelines which are laid for long distances will go through different terrains and different climatic conditions. There is a need to analyse the behaviour of pipelines subjected to different conditions and there is need to study the stress analysis for the particular materials. Scholars from different parts of the world made researches on the pipelines of different working conditions they may be of internal conditions like maximum and minimum working temperatures, maximum and minimum working pressures and fluid density and may be of external conditions like climate, weather, moisture content, soil, seismic effects, wind velocity, temperatures, pressures and etc. This paper gives a brief description of the analysis and research made on the stress analysis by research scholars considering different conditions applied on the pipeline carrying fluids particularly natural gas in some papers.

II. REVIEW

2.1 In the paper titled "**Stress analysis of oil and gas pipeline parallel laying when traversing tunnels**", the authors **Kun Huang, Shijuan Wu, Liqiong Chen, Hongfang Lu, YitangLv and Jiali Wu** dealt with stress on pipes that are laid parallel in tunnels. From this the main load infector effecting oil & gas pipeline stress, and the location of the most dangerous section is obtained. The software Caesar II has been used to make numerical simulation on one section of oil and gas parallel laying pipeline. ASME B31.4 is used as the guidelines for the designing of pipeline. They have considered pipeline containing oil and stated that stress caused is mainly due to gravity, inner pressure etc. They have suggested to reinforce and add the pipe constraint at tunnel portals, or to change the pipeline direction to absorb a part stress using the nature bends at tunnel portals.

2.2 **Mr. Xiaonan Wu, Mr. Yi Jiang, Mr. Hongfang Lu** and **Mr. Shijuan Wu** in this paper "**Stress Analysis of Shallow Sea Gas Pipelines**", analyzed the stresses and displacements for the pipes that are passing through shallow sea. The method used are the underground method and above the sea-bed method. And determined to be safe. It is identified that the position of the stress key point of shallow sea gas pipelines is at the pipe bends. They found that on comparison between the two laying modes, the operating stress of straight underground pipeline tends to be slightly lower than that of sea-bed pipeline, while the stress value of sea-bed pipeline at pipe bends tends to be significantly lower than that of underground pipelines. Neither of the maximum operating stresses exceed the limit value [σ] thereby meeting the safety requirements, so both of the laying methods are safe. Therefore, it is necessary to combine safety, economics and construction difficulties when determining which kind of shallow sea pipeline laying mode can be chosen.

2.3 In the paper "**Failure analysis of stress corrosion cracking occurred in a gas transmission steel pipeline**", the authors **E.SadeghiMeresht, T.ShahrabiFarahani and J.Neshati** dealt with failure mechanisms of pipeline. It revealed that polyethylene tape coating on the external surface of the pipeline has been disbonded resulting in exposure to atmosphere. In

this study, they have determined failure mechanisms based on available documents and metallographic studies conducted on this pipeline. Their analysis showed that the applied polyethylene tape coating on the external surface of the pipeline was open and disbonded in the corroded area causing external surface of buried pipeline to be exposed to wet soil around it. As a result of the chemical interactions and formation of carbonate/bicarbonate solution is the reason for the presence of tensile stresses and stress corrosion cracking occurred in the longitudinal direction and at the outer surface of the pipe.

2.4 In another paper "**Stress Analysis of Buried Gas Pipeline Traversing Sliding Mass**", the authors **Liqiong Chen**, **Shijuan Wu**, **Hongfang Lu**, **Kun Huang**, **YitangLvandJiali Wu** dealt with stress on pipes that are buried in the area prone to landslides. The junction of the conventional buried pipeline and the landslide has been confirmed as coming under the heaviest loads. Therefore, they have stated that stress checks against accidental loads should be emphasized during the stress analysis of gas pipelines traversing sliding masses. The designing of the gas transmission pipeline is based on ASME B 31.8 standard guidelines. They have found that When a gas pipeline laterally traverses a slide mass, the pipeline stress is greatly influenced, but the impact on the pipeline is smaller when traversing longitudinally. As a result, priority should be given to designing longitudinally traversing pipelines whenever possible.

2.5 In this paper "**Stress Analysis of Gas Pipeline in Tunnels on Pressure Testing Condition**", the authors **Xiaonan Wu, Haowen Shu, Kunrong Shen** and **LinfengZan**dealt with stress analysis model for gas transmission pipeline in shaft of shield tunnel on pressure testing condition by CAESAR II software. They have determined gas pipe stress distribution, clearly determined the stress key points, and checked the strength of the pipeline. This method provides guidance for gas pipeline stress analysis. According to the comparison study of primary stress, secondary stress and the stress caused by weight, it is found that on the higher testing pressure, internal pressure is the main factor which produced the pipe stress and temperature, the weight of pipeline and the medium in pipeline has a little effect.

2.6 In the paper "**Analysis of fiber reinforced composite pipe under the effect of torsional loading**", the authors **Mehmet hanifidoğru** and **Eyüpyeter** dealt with study on stress and deformation analysis of multi-layered thin-walled fiber reinforced composite pipes subjected to torsional loading. Usage areas of structures produced using composite material is increasing from days to day. Production of pipes and rods using fiber reinforced composites is also increasing. According to loading conditions, composite structures can be designed by using different fiber orientation angles. Fiber orientation angle is one of the most critical parameter for the fiber reinforced composites due to stress, deformation and failure analysis. Hence composite pipe layers are modelled at different fiber orientations such as: [0/90], [15/75], [30/-60] and [45/-45]. Also effects of different diameters, thickness and length of the composite pipes under the effect of torsional loading conditions are analyzed. These analyses are performed using finite element analysis program ANSYS to obtain stress and deformation values.

2.7 **Mr. Matías Alvarado, Miguel A. Rodríguez-Toral, Armando Rosas and Sergio Ayala**in this paper "**Decision-making on pipe stress analysis enabled by knowledge-based systems**", presented engineering decision-making on pipe stress analysis through the application of knowledge-based systems (KBS). Stress analysis, as part of the design and analysis of process pipe networks, serves to identify whether a given pipe arrangement can cope with weight, thermal, and pressure stress at safe operation levels. An iterative process of design and analysis cycle is done routinely by engineers while analyzing the existing networks or while designing the process pipe networks. In their proposal, the KBS establishes a bidirectional communication with the current engineering software for pipe stress analysis, so that the user benefits from this integration. The stress analysis knowledge base is constructed by registering the senior engineers' know-how. The engineers' overall strategy to follow up during the pipe stress analysis, to some extent contained by the KBS, is presented. Advantages in saving engineering man-hours and usefulness in guiding experts in pipe stress analysis are the major services for the process industry.

2.8 **Mr. T. Sawa, N. Higurashi** and **H. Akagawa**in this paper "**A Stress Analysis of Pipe Flange Connections**", presented the use of pipe flange connections is standardized in the codes of JIS, ASME, DIN and so on. However, these codes are almost entirely dependent on experience, and subsequently some problems concerning pipe flange connections have been encountered. In this paper, the distribution of contact stresses which governs the sealing performance is analyzed as a three-body contact problem, using an axisymmetric three-dimensional theory of elasticity. The effects of the stiffness and the thickness of raised face metallic gaskets on the contact stresses and the effective gasket seating width are shown by numerical calculation. Moreover, stresses produced on the hub, the load factor (the relationship between an increment of bolt axial force and an internal pressure), and the maximum stress caused in bolts are analyzed. For verification, experiments are carried out. The analytical results are satisfactorily consistent with the experimental results.

2.9 **Mr. Toshiyuki Sawa, Naofumi**and **Takahito Nishida** in this paper "**Stress Analysis and Determination of Bolt Preload in Pipe Flange Connections With Gaskets Under Internal Pressure**", presented the stresses of a pipe flange connection with a spiral-wound gasket under internal pressure and are analyzed taking account a nonlinearity and a hysteresis of the gasket by using an axisymmetric theory of elasticity and the finite element method (FEM). The leakage tests were also conducted using an actual pipe flange connection with a spiral-wound gasket. Using the contact stress distribution of the pipe flange connection with 3-in. nominal diameter under internal pressure and the tightness parameter, the values of the new gasket constants are obtained by taking into account the changes in the contact stress. A difference in the new gasket constants between the estimated values obtained from the actual pipe flange connection and the values obtained by the PVRC procedure is small. In addition, a method to determine the bolt preload for a given tightness parameter is demonstrated. The obtained results of the bolt preload

for the pipe flange connection are in a fairly good agreement with those obtained by the PVRC procedure under a lower pressure application. However, a difference in the bolt preload is about 10% when an internal pressure is increased.

2.10 In the paper titled "**Analysis of Hot Oil Pipeline Stress Influencing Factors**'", the authors **Wu Xiaonan, Wu Shijuan, Lu Hongfang, Wan Jie, Liu Jiali, Li Weitao** and **Liu Zilin** explored the main factor of hot oil pipeline stress and the location of key points. Analysis of the impact of changes in temperature and pressure on piping stress when hot oil pipeline running, draw hot oil pipeline stress distribution, clearly identifies the location of key points of stress concentration, and that temperature is a major factor in generating pipe stress. In order to reduce the viscosity of crude oil for transport, we often use the way of heating delivery for high pour point, high wax, and high viscosity oil. Crude oil at high temperature, through long-distance transmission, the temperature and pressure changes on the piping stress greater impact. Primary stress and the secondary stress are generated at the starting point in the first station. According to multiple stress, primary stress and the secondary stress contrast, that temperature is a major factor in pipe stress generated, and pipe weight, pipe internal medium weight and pressure impact of stress on the pipeline has little effect.

2.11 In the paper titled "**Analysis of Suspended Pipeline Stress Sensitivity**", the authors **Wu Xiaonan, Lu Hongfang, Wu Shijuan, Huang Kun, Chen Xi, Kang Fuxin** and **Liu Zilin** studied and suggested that Natural gas pipeline laying process will inevitably go through some of the earthquake-prone areas, these areas of soil subsidence, will cause the pipeline vacant, vacant section of the pipeline failure may cause pipeline rupture. Effects of suspended pipeline stress safety usually have two factors: suspended length and the buoyancy of water. Their Research shows that suspended length of pipe is having a greater sensitivity on pipeline stress, and the buoyancy of water is relatively small. The results provide some reference for safety management and selection of pipeline.

2.12 In the paper titled "**GPRS based Remote Data Acquisition and Forecasting System for Long-distance Natural Gas Pipeline Monitoring**", the authors **Xiaoyan Zhao, Zhaohui Zhang** and **Wei Meng** presented a General Packet Radio Service (GPRS) based remote data acquisition and forecasting system, which monitors the geological disasters along the natural gas pipeline under the ground. The field data terminal units (DTU) collect data from the sensors installed on the pipe, and transmit the data by GPRS module to the server in the control center. The server processes the data, broadcasts on the website, and forecasts abnormal variation in time. Three years' operation in site shows the system is effective and feasible. Wireless based data acquisition solutions are widely used in many fields like structure monitoring, transportation or environmental studies. With the development of wireless communication, GPRS gives the possibility to get the data from the remote devices in the field by the mobile networks throughout the nation. The long distance pipeline monitoring system demonstrated the measurement system is effective and feasible. This system also can be generalized to other fields.

2.13 In the paper titled "**Optimization of Natural-Gas Pipeline Systems via Dynamic Programming**", the authors **Peter j Wong** and **Robert e. Larson** presented the application of dynamic programming techniques to solve optimization problems that occur in the short-term (transient) terminal distribution and long-term (steady-state) transmission of natural gas. The complexity and expense of operating natural-gas pipeline systems have made optimum operation and planning of increased interest to the natural-gas pipeline industries. Since the operations of natural-gas pipeline systems are characterized by inherent nonlinearities and numerous constraints, dynamic programming provides an extremely powerful method for optimizing such systems. The first was the dynamic optimization of a single compressor and single pipeline combination, which is physically located just ahead of the consumer delivery point. The second was the static optimization of a long series combination of compressors and pipelines required to transmit gas from the source wells to the region of consumer delivery.

2.14 In the paper titled "**The Calculation of Multilayer Polymer Pipes Using Finite Elements and their Application to Gas and Oil Pipelines**", the author **YuryReutov** presented the analysis of multilayer polymer pipes application in the Oil and Gas Industry, and calculation of their stress-strain state using the finite element method (FEM). The proposed numerical method for estimating stress strain state of multilayer polymer pipes can be used for improvement in the normative documents for the design of pipeline systems from polymeric materials; in the preparation of tables and nomograms in view of modern requirements for the determination of wall thicknesses, strength and stability testing of pipelines of different materials, varying pressures, axial loading and bending applications and other operational factors. In addition, the proposed method, using statistical data on the limiting strength properties of the material and parameters of the stress-strain state, will assess the reliability of pipeline systems.

2.15 In the paper titled "**Stress corrosion failure of high-pressure gas pipeline**", the authors **F. Hasan, J. Iqbal** and **F. Ahmed** presented the Incidents of failure due to corrosion/stress corrosion cracking of high-pressure gas pipelines in Pakistan have been observed to occur after about 15–20 years of service. The present paper constitutes the failure analysis of an 18-inch diameter electric resistance-welded gas pipeline. The failure was characterized, on the basis of all the available evidence and the metallurgical examination carried out on the ruptured pipe, as a stress corrosion failure that had initiated at a longitudinal 'stress raiser'. This stress raiser, which was essentially a manufacturing defect, constituted a longitudinal 'step' on the pipe surface that had resulted from the faulty trimming/shaving of the weld flash. The findings of this study, thus, emphasize the need for the care that must be taken during the shaving-off of the weld flash.

2.16 In the paper titled "**Analysis of service stress corrosion cracking in a natural gas transmission pipeline, active or dormant?**" the authors **J.Wang**and**A. Atrens**dealt with Stress corrosion cracks (SCC) had been found in a natural gas transmission pipeline during a dig-up and inspection program. The question was raised as to whether the SCC was active or dormant. This paper describes the resultant investigation to determine if a particular service crack was actively growing. The strategy adopted was to assess the appearance of the fracture surface of the service crack and to compare with expectations from laboratory specimens with active SCC. The conclusions from this study are as follows. To judge whether a crack in the service pipe is active or dormant, it is reasonable to compare the very crack tip of the service crack and a fresh crack in a laboratory sample. If the crack tip of the active laboratory sample is similar to that of the service pipe, it means the crack in the service pipe is likely to be active. From the comparison of the crack tip between the service pipe and the laboratory samples, it appears likely that the cracks in the samples extracted from service were most likely to have been active intergranular stress corrosion cracks.

2.17 In the paper titled "**Vulnerability Assessment of Buried Pipelines: A Case Study**", the authors **ChennaRajaram, Srikanth Terala, Ajay Pratap Singh, Kapil Mohan, Bal Krishna Rastogi,** and **Pradeep Kumar Ramancharla**dealt with the pipeline systems that are commonly used to transport water, sewage, oil, natural gas and other materials world over. These pipelines run over long distances and in some instances they cross high seismic areas including fault crossings. Many buried pipelines in India run through high seismic areas and are exposed to considerable seismic risk. These pipelines should be designed in such a way that they remain functional even when they are subjected to high intensity earthquake shaking. This paper illustrates the performance of one of the high pressure gas pipeline in the state of Gujarat, under the fault movement. Analysis shows that the burial depth of pipeline should be minimized in the fault zones in order to reduce soil restrain on the pipeline during fault movement. The optimum angle of fault crossing will depend upon the dip plane and the expected type of movement. And it should be within 90°. Abrupt changes in wall thickness should be avoided within fault zone. In all areas of potential ground rupture, pipelines should be laid in relatively straight section avoiding sharp changes in direction and elevation. The burial depth of pipeline should be minimized within fault zones in order to reduce soil restrain on the pipeline during fault movement.

2.18 In the paper titled "**Numerical simulation of temperature field and residual stress in multi-pass welds in stainless steel pipe and comparison with experimental measurements**", the authors **Dean Deng** and **HidekazuMurakawa** presented the procedure for analyzing temperature fields and residual stress states in multi-pass welds in SUS304 stainless steel pipe. Based on the ABAQUS software, uncoupled thermal–mechanical three-dimensional (3-D) and two-dimensional (2-D) finite element models are developed. The finite element models are employed to evaluate the transient temperature and the residual stress fields during welding. Firstly, a 3-D model is developed to simulate the temperature fields and welding residual stresses. Secondly, based on the characteristics of the temperature fields and the welding residual stress fields, a 2-D axisymmetric model is also developed. The simulated result shows that the 2-D axisymmetric model can be effectively used to simulate the thermal cycles and the welding residual stresses for SUS304 stainless steel pipe. Using the 2-D model, a large amount of computational time can be saved. In this study, experiments are also carried out to verify the effectiveness of the proposed numerical models. The results of both 3-D model and 2-D model are in very good with the experimental measurements.

III. CONCLUSION

Based on previous papers and researches on stress analysis of pipelines, it is found that there are many design modifications raised by the research scholars in order to withstand conditions as considered. There are wide range of materials that are analysed in such a way that whether the pipelines are going to withstand the stresses or not. It is observed that the most of the failures is due to the stress concentration on a particular region. Thus, to avoid failure of the pipelines there is a need to distribute the load and stress across a large portion of the pipelines. To extend this project it is suggested that apart from the stress distribution, replacement of materials with the newly invented materials and providing extra reinforcement layer around pipeline will be useful in rectifying majority of failures due to stress in pipelines.

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