International Journal of Mechanical Engineering (IJME)
ISSN(P): 2319-2240; ISSN(E): 2319-2259
Vol. 4, Issue 6, Oct - Nov 2015, 57-66

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

FAILURE ANALYSIS OF THE FLOWLINE OF CRUDE OIL IN PIPES

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ABSTRACT

The study of failure analysis is wide and the failure in materials and machineries is much dreaded in manufacturing establishments. The materials used for pipelines must be of good mechanical properties, low cost and readily available. Carbon steel is mostly used due to low resistance level. The failure analysis comes to relevance in order to prevent the menace attached to these failures, such as: financial losses, dangers to workers and personnel, production breakdowns and also the likelihood to spark up an epidemic.

Our sources of research material are from library, online publication, questionnaire survey, oral interview, physical observation, use of mathematical model and computer aided design. A C^{++} programme and Solid work were used in the analysis of failure by varying the pressure, diameter and pipe thickness as the fluid flows. The results obtained shows that as operating pressure increases at constant diameter of pipe, stress induced in the pipe increases. It also shows the rate at which liquid flow through the pipe at various operating pressures and diameter. The model gave the thickness of the pipe to be not less than 0.25 inch (6.35mm).It also gave a pressure drop of 21.11 psi (145.55 KN/m^2) for every one Kilometer.

KEYWORDS: Failure Analysis of the Flowline of Crude Oil in Pipes

INTRODUCTION

Failure analysis is an important topic in material selection since failure of components and materials of most machines and machineries is one of the most dreaded situations in any manufacturing industry. In the oil and gas industry, piping is widely applied in the transportation of the fluid (either crude or refined) from one point to another. The design and laying of these pipes (flow lines) are monitored with utmost scrutiny in order to prevent any form of wastage in production. Break down in production is generally due to failure of these pipes.

Pipeline is commonly made of carbon steels which have good mechanical properties, low cost and readily available, though they have low corrosion resistance compared to other corrosion resistance material. Normally, as an oil well ages, the production of oil starts to decline whereas water and gas flow rates tend to increase. The presence of high corrosive agents such as CO_2, H_2S and chlorine compounds which are dissolved in the fluids can accelerate corrosion process inside the pipeline. Therefore, the impact of changes in fluid composition on a pipeline should be anticipated during maintenance program.

Failure analysis in flow line of crude oil we be looked into the area of the effects of flow rate, pressure, diameter and thickness variation of pipe in the crude oil pipeline. This can occur as the crude oil is been transport from the point of drilling in the oil well to the storage tank where it is to be stored for the refining stage. The project focuses on finding suitable operating pressures and diameter coupled with knowing the amount of pressure drop within the pipeline and at what point the stress build up to cause failure.

MATERIAL SELECTION FOR PIPELINES

Material selection shall be optimized, considering investment and operational costs, such that Life Cycle Costs (LCC) are minimized while providing acceptable safety and a well-designed pipeline with more reliability. Key factors that apply to materials selection:

- Primary consideration shall be given to materials with good market availability and documented fabrication and service performance.
- The number of different material types shall be minimized considering costs, interchangeability and availability of relevant spare parts.
- Design life.
- Operating conditions.
- Experience with materials and corrosion protection methods from conditions with similar corrosives.
- System availability requirements.
- Philosophy applied for maintenance and degree of system redundancy.
- Weight reduction.
- Inspection and corrosion monitoring possibilities.
- Effect of external and internal environment, including compatibility of different materials.
- Evaluation of failure probabilities, failure modes, criticalities and consequences. Attention shall be paid to any adverse effects material selection may have on human health, environment, safety and material assets.
- Environmental issues related to corrosion inhibition and other chemical treatments.

METHOD OF STUDY

This research involved a full understanding of the concept of failure. The methods used in this study involve the following;

- Library and online research material
- Questionnaire survey and oral interview
- Mathematical model and Computer Aided Design

Field Survey

In order to examine the root cause of failure, several cases of failure that have occurred were critically looked into. Selected team of field workers, inspection officers were posed with questions based on failure in flow lines. So many questions were asked and the answer collated. Detailed studies usually require documentation of service history (time, temperature loading environment etc) along with chemical analysis, photomicrographs and the like

Computer Aided Design

Use of computer programme C^{++} and Auto Inventor was extensively used in this project work. C^{++} was used to analyze data gotten from industry to give a better operating pressure with a perfect diameter and to monitor the pressure drop along the pipeline. The solid work design shows the effect of stress caused on the pipe due to variation of operating pressure and diameter of the pipe.

Mathematical Model for Stress Analysis through Computational Method

The flow line thickness varies from different sections to another due to variation in pressure and temperature. The thickness of the flow line from the well to the flow station and finally to the refinery or terminals must not be minimum to the one needed for a specified pressure and temperature. These parameters are represented in the equation below:

$$t_m = \frac{PD}{2(SE + Py)} + C \qquad 3.1$$

Where,

t_m=Minimum flow line wall thickness (in) allowable on inspection

P=Maximum internal service pressure gauge ($1b/in^2$)

D=Outside diameter of pipe (in)

S=Maximum allowable stress in material due to internal pressure ($1b/in^{2)}$)

E=Quality factor

Y=A coefficient, values for which is in the standard code

C=Allowance for threading mechanical strength and corrosion (in) with values listed in the standard code.

Stresses in members are also given by the equation 3.2:

$$S_m = \frac{F_m}{A_m} \qquad 3.2$$

Where, K_m=spring constant of member

F_m=Tensile force in the bolt

U_m=the amount by which the member is extended when it is loaded from zero to f_m

S_m=Stress in member

A_m=Area of the member

Pressure Drop in Pipelines

The pressure drop in pipe, due to friction is a function of the fluid flow-rate, fluid density and viscosity, pipe diameter, pipe surface roughness and the length of the pipe. It can be calculated using the equation below:

$$\Delta P_f = 8f\ ({}^{L}/_{di})\frac{\rho u^2}{2} \qquad 3.3$$

ΔP_f = Pressure drop, N/m^2

f = Friction factor

L = Pipe length, m

d_i = Pipe inside diameter, m

$\boldsymbol{\rho}$ = fluid density, Kg/m^3

u = fluid velocity, m/s

DATA PRESENTATION

The data below present the constant, coefficient and values used in the calculation and modeling.

Table 4.1: Values of Coefficients and Constant Used

Description		Value	Units
Type of system Hazardous liquid			
Accident type: Pipe failure and leak			
Material release: Crude oil API 35.6º			
MOP	Maximum operating pressure	800	Psi
D	Outside diameter of pipe	12.750	In
S	Specified minimum yield strength	42,000	Psi
T	Normal wall thickness of pipe	0.25	In
F	Design factor (quality factor E)	0.72	
T	Temperature derating factor (normally 1.0)	1	
C	Maximum depth of corroded area	0.080	In
C/t	Pit depth percentage	32.0	%
G	Constant for maximum allowable Pressure	3.00	
Pd	Safe maximum (derated) pressure for corroded area	11,100	Psi
U	Fluid velocity	0.4	m/s
f	Friction factor	0.07	µ
Year in service period of pipe is between (1993-2001)		6	Years

Source: - Niger-Delta oil producing company (confidential data)

Data was obtain during failure of the pipeline

Calculations and Analysis

The data was analyzed using C++ programming and it was obtained that the amount of stress exacted on the pipe during the time of failure was 41222.22 ib/in2. The model gave the thickness of the pipe suitable for the flow that will nocause failure be not less than 0.25 inch (6.35mm) from equation 3.1.

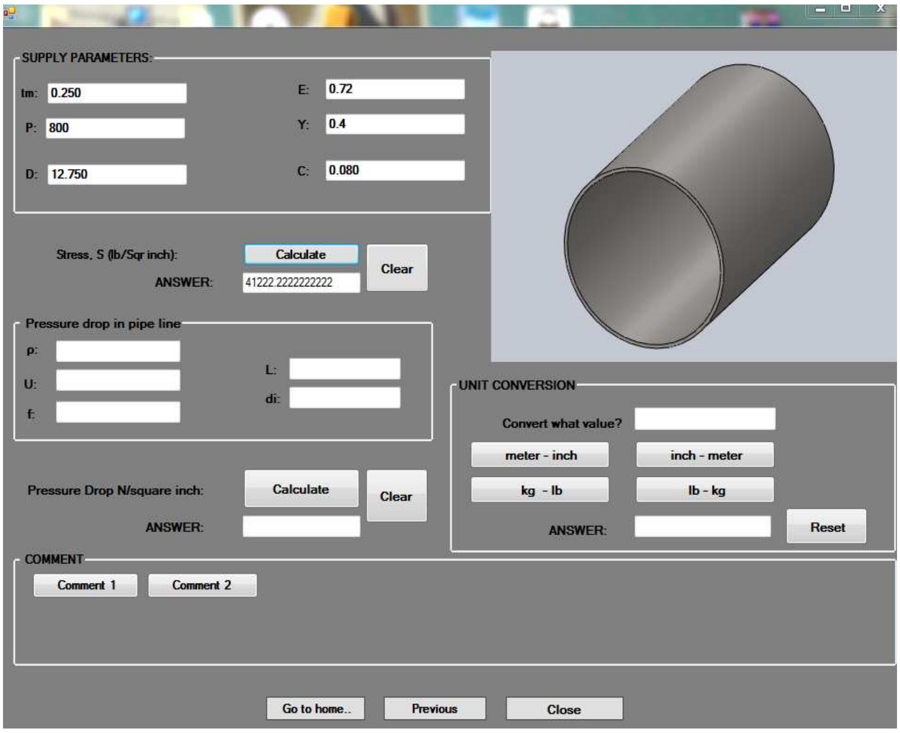

Figure 4.1: C^{++} Programme Interface Showing the Calculation of Stress Exacted on the Pipe at 800 Psi

Analyzing the Stress Induced in the Pipe Varying Both Pressure and Diameter

The table below shows the result generated by varying the diameter of the pipe while the operating pressure remains constant.

Table 4.2: Variation of Pipe Diameter at Constant Maximum Operating Pressure of 800 Psi

MOP	Diameter of Pipe (in)	Stress Induced in the Pipe (ib/in^2)
800	9	28967.3202
800	10	32235.2941
800	11	35503.2679
800	12	38771.2418
800	12.75	41222.2222

Table 4.3 depicts the effect variation of the operating pressure at constant diameter pipe of 11 inchesand the induced pressure resulting in the pipe.

Table 4.3: Variation of Operating Pressure at a Constant Pipe Diameter of 11 Inches

MOP	Diameter of Pipe (in)	Stress Induced in the Pipe (ib/in^2)
700	11	31065.3594
750	11	33284.3137
800	11	35503.2679
850	11	37722.2222
900	11	39941.1764

Table 4.4 shows the effect of varying the operating pressure at constant diameter of 12 inches and the induced stresses generated.

Table 4.4: Variation of Operating Pressure at a Constant Pipe Diameter of 12 Inch

MOP	Diameter of Pipe (in)	Stress Induced in the Pipe (ib/in^2)
700	12	33924.8366
750	12	36348.0392
800	12	38771.2418
850	12	41194.4444
900	12	43617.6471

Table 4.5: Variation of Operating Pressure at a Constant Pipe Diameter of 12.75 Inch

MOP	Diameter of Pipe (in)	Stress Induced in the Pipe (ib/in^2)
700	12.75	36069.4444
750	12.75	38645.8333
800	12.75	41222.2222
850	12.75	43798.6111
900	12.75	46375

Simulation of Effect of Stress along the Pipe

The simulation of the effect of stress on the pipe at some selected operating pressure and diameter was carried out using Solid works and is depicted below:

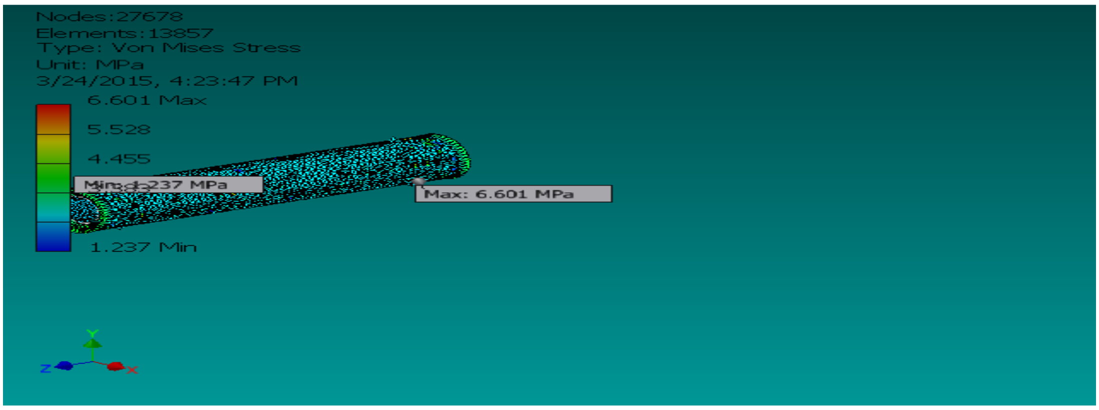

Figure 4.2: Simulation of the Effect of Pressure at 5.5158MPa (800 psi) on a 10 Inch Pipe

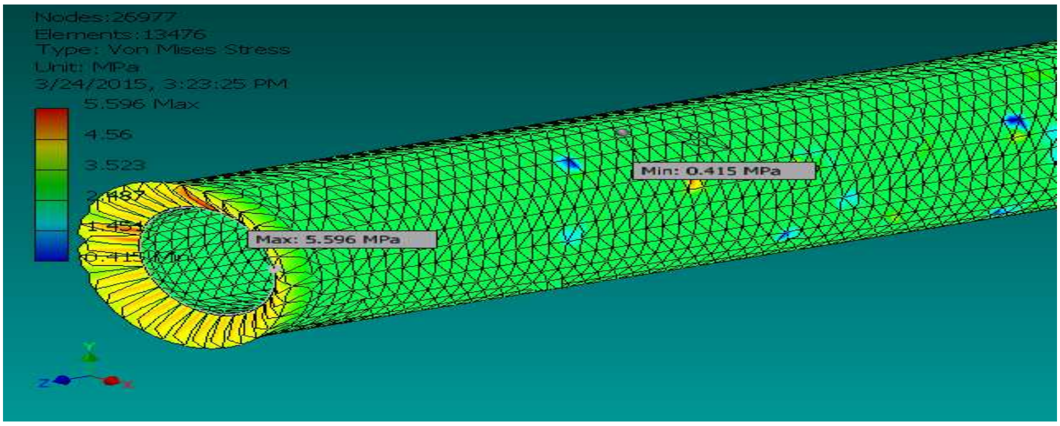

Figure 4.3: Simulation of the Effect of Pressure at 5.5158MPa (800 psi) on a 12 Inch Pipe

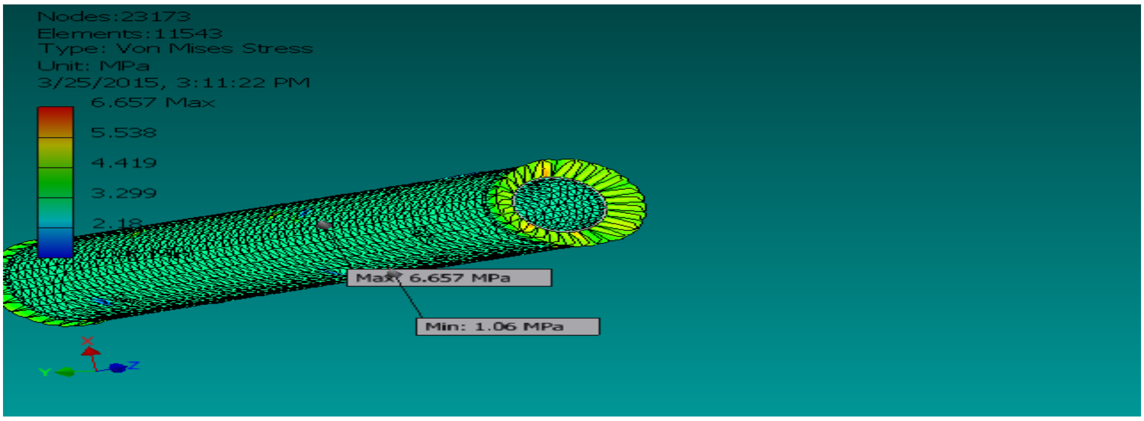

Figure 4.4: Simulation of the Effect of Pressure at 4.8263 MPa(700 psi) on a 11 Inch Pipe

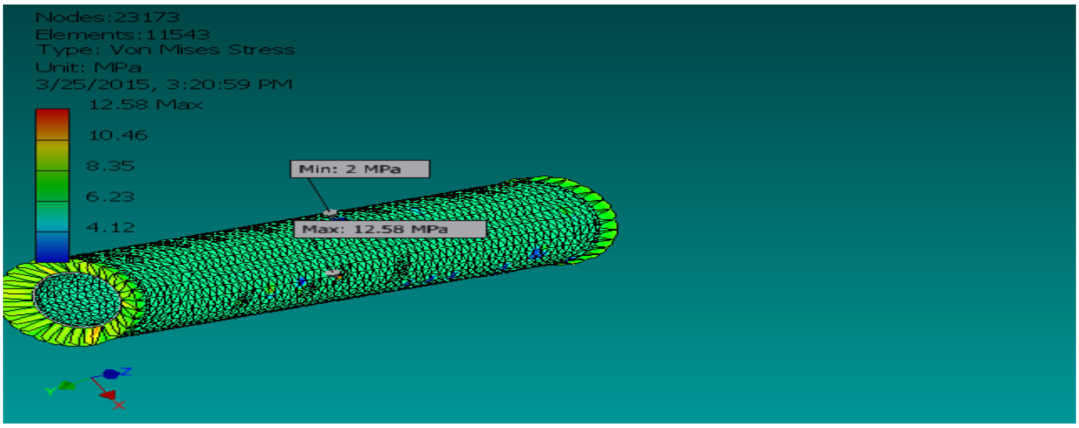

Figure 4.5: Simulation of the Effect of Pressure at 5.5158 MPa(800 psi) on a 11 Inch PIPE

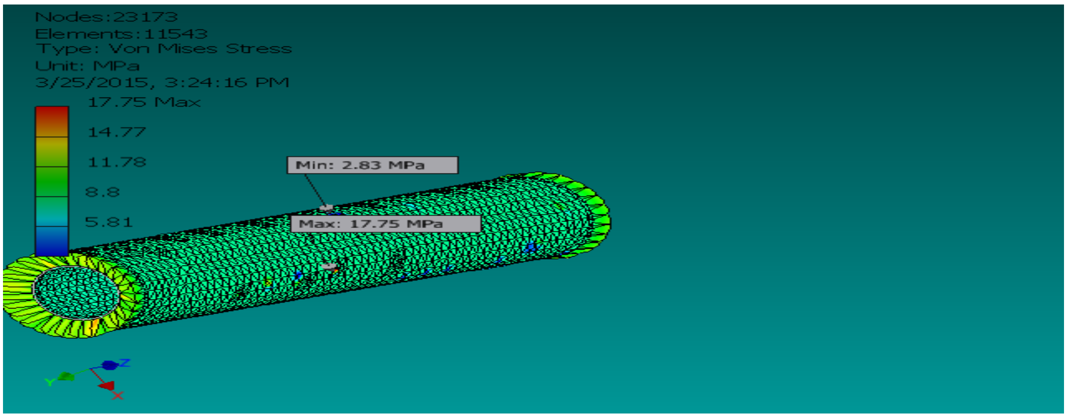

Figure 4.6: Simulation of the Effect of Pressure at 6.2052 MPa(900 psi) on a 11 inch Pipe

Pressure Drop Calculation

The pressure drop in the pipe is calculated from the equation 3.3

$\Delta P_f = 8f\ ({}^{L}/_{di})\frac{\rho u^2}{2}$

f = 0.07 µs

L = 1000m (1Km)

d_i = 10.25 in

$\boldsymbol{\rho}$ = 847 for API 35.6

u = 0.4 m/s\

The pressure drop was also calculated by writing C^{++} programme for the equation 3.3 The resulting analysis using the programme shows that the pressure drop in the pipe for every 1000m (1Killometer) is 21.11 psi. The typical station been used as our study will require that at every 38 km , there should be a pressure booster in place to increase the pressure back to the maximum operating pressure. Figure 4.7 shows the pressure drop calculation from the C^{++} programme.

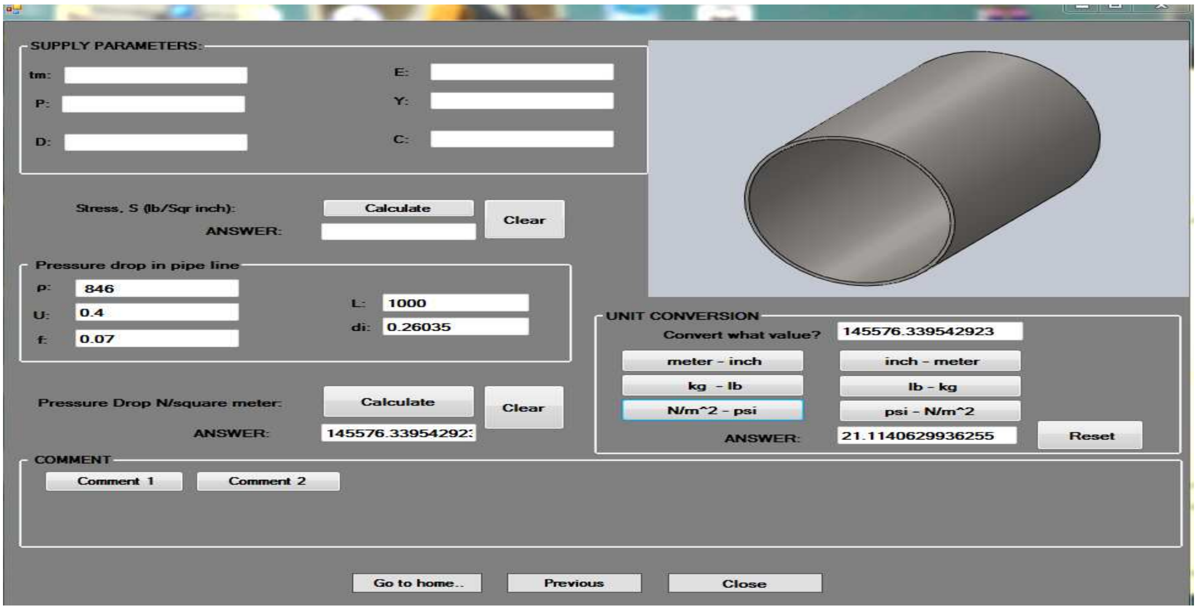

Figure 4.7: Result Obtained from C^{++} Programme Showing the Stress That was Induced in the Pipe during Failure

DISCUSSIONS

Table 4.2 shows that at constant operating pressure, and varying the diameter, the induced pressure increases, Also when the pressure is varied and diameter constant (Table 4.3, 4.4 and 4.5) the induced stresses is still on the increase as the pressure increases. This shows that the pressure and diameter have effect on the induced stresses in the pipe. The simulation of this result from inventor is depicted on Figure 4.2 to figure 4.6.. For the 12 inch pipe, the pipe experiences much pressure at the opening and edge. In all pressure distribution in the pipe shows that stress is much concentrated at the edge/opening of the pipe

CONCLUSIONS

It can be concluded that a pressure of 800 psi (5.5158 Mpa) and pipe diameter within 10 inch (254 mm) -11 inch (279 mm) is suitable for use, due to the pressure distribution observed through the Auto Inventor design software and no failure occurred.

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