Analyzing Pressure Dynamics in Crack Pipeline Systems without Leakage

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April 2024 **Golan 2724**

ABSTRACT

The research investigates the impact of cracks on crude oil flow in pipelines. Unlike widely studied leaking fractures, this study focuses on non-leaking cracked pipes. Experiments were conducted using a 24 mm diameter, 2 m long horizontal pipe to measure velocity and pressure. Various crack sizes were tested, and results showed increased head loss in the crack zone compared to upstream and downstream areas. The study also used ANSYS to simulate the flow behavior and solve motion equations, comparing theoretical pressures with experimental data. Findings revealed a direct relationship between crack size and pressure loss, with larger cracks causing greater pressure drops.

KEYWORDS Simulation, pipeline, head loss, crude oil.

Introduction

Pipeline is the most significant process for transferring energy in the world. It is important to preserve high-pressure oil and gas pipeline arrangements security and reliability, because the products are hazardous and possibly will lead to fire, exploding, and toxicity and result in substantial economic damages, fatalities, and ecological contamination [1]. The pipelines applied to transfer petroleum and other chemical products need to be constructed from typical materials which are resistant to high stress and corrosion. In spite of the growth in this sector, cracks and leakages are distinguished in a variety of industries worldwide. In many areas of pipeline integrity evaluation, material properties play a major role for instance it has been applied in a fracture mechanics-based exhaustion life evaluation, the position of both the crack development rate properties and the material static strength characteristics (i.e. yield strength, ultimate strength) [2].It has been presented that the most economical and most commercial networks for oil and gas pipe complexes are the innocuous means of conveying crude oil and fulfilling a strong request for quality and trustworthiness [3].While there may be a number of cyclic fatigue loading in a pipeline structure (mechanical vibration and thermal loads), the subsequent report focuses on interior cyclic pressure instigated fatigue, where under some conditions the internal pressure fluctuations encountered by a pipeline may lead to the initiation and propagation of fatigue crack [4].

Leak detection technologies have been playing an important role in protecting the safety of pipeline transportation [5]. The leaking detection could be by hydrostatic testing, infrared, and laser technology. In this research, it is intended to detect the causes of fracture right from beginning before the problems raise. It is known that most of the fractures start from small crack then enlarge till damage the pipe. The investigations on cracks in pipelines are limited. Researchers focus on the fractured pipe where leaking occur. Crack in the pipe have a great impact on hydraulic efficiency of pipe lines and results in minimizing the pressure head and discharge in the pipe systems [6]. [7] studied the correlation between the head loss of a fluid in cross fissures and the width as well as roughness of the fissures. Related to the models for the estimation of load losses in pipes, other researchers developed a theoretical experimental equation take in consideration the flowed and dense phases [8].

Methodology

The methodologies for formulating the research has based on the primary data, in which two tanks (Tank A and Tank B) were prepared for achieving the main objectives of the research. The pressure head in the tank A was greater than the head in the tank B. in the figure (1) The outlet in the tank A is at the same level of inlet of tank B. Furthermore, the carbon steel pipe which was appropriate for transporting crude oil was used in conducting the experiment. The inside and oust side diameters of the pipe were 20mm and 25mm respectively. Followed by tank A, there has been a valve in the beginning the pipe to control the amount of discharge in the pipe. A pump was established for the purpose of increasing pressure in the carbon steel pipe. The fluid flow considered along the pipe is monophasic liquid crude oil with constant properties such as density of 841 kg/m^3 and viscosity of 0.003704 kg/ (m.s). The flow regime is considered turbulent since the velocity magnitude in the inlet zone is specified to be 0.2m/s.

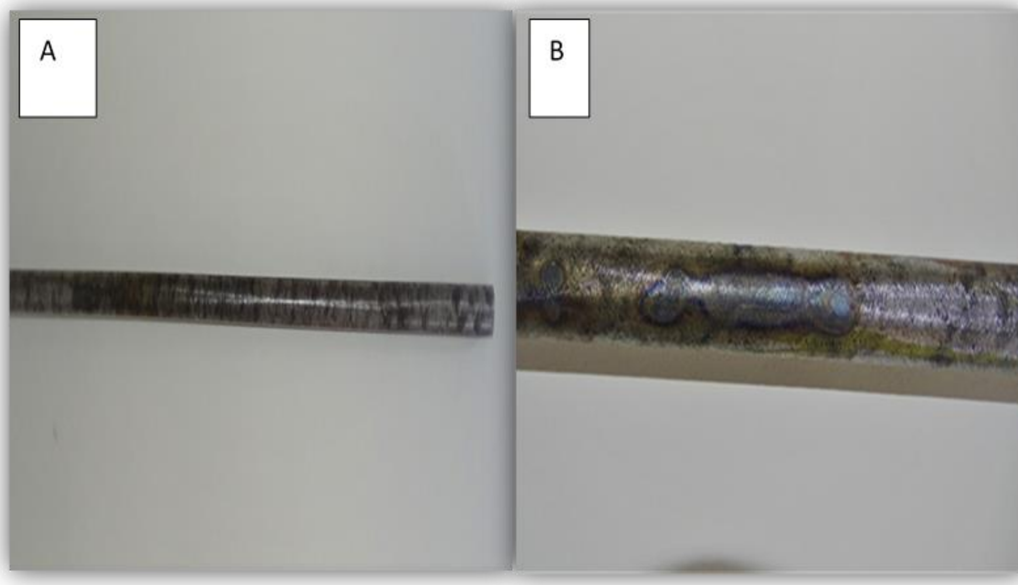
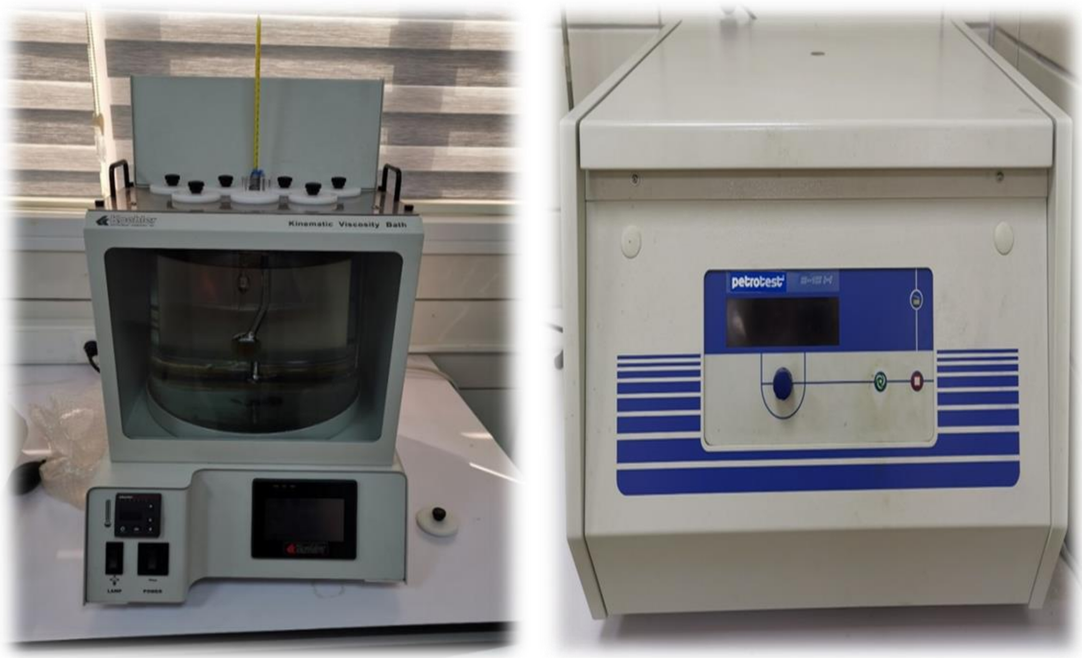


Figure (1) (A) Carbon steel pipe, (B) Cracked carbon steel pipe.

The crude oil viscosity tested by kinematic viscosity physical bath which is applied for the estimation of translucent liquids and opaque liquids. Viscometer constant is independent of the temperature with a suspended level viscometer. Therefore, it is recommending to use suspended-level viscometers for testing in combination with the TV12 when using the bath at different temperatures.

The standard describes the manual measuring of determination of kinematic viscosity. Measure the time for a capacity of liquid, transparent or opaque; to movement under gravitational force through an adjusted glass vessel viscometer.

The viscometer size depends on the sample to be tested. Flow times between 200 and 900 seconds are recommended. The viscometer has to be in a suspended vertical position This is possible with Tamson stainless steel viscometer holders. They are available for most of the ASTM D446 viscometers as shown in Figure (2) [9].

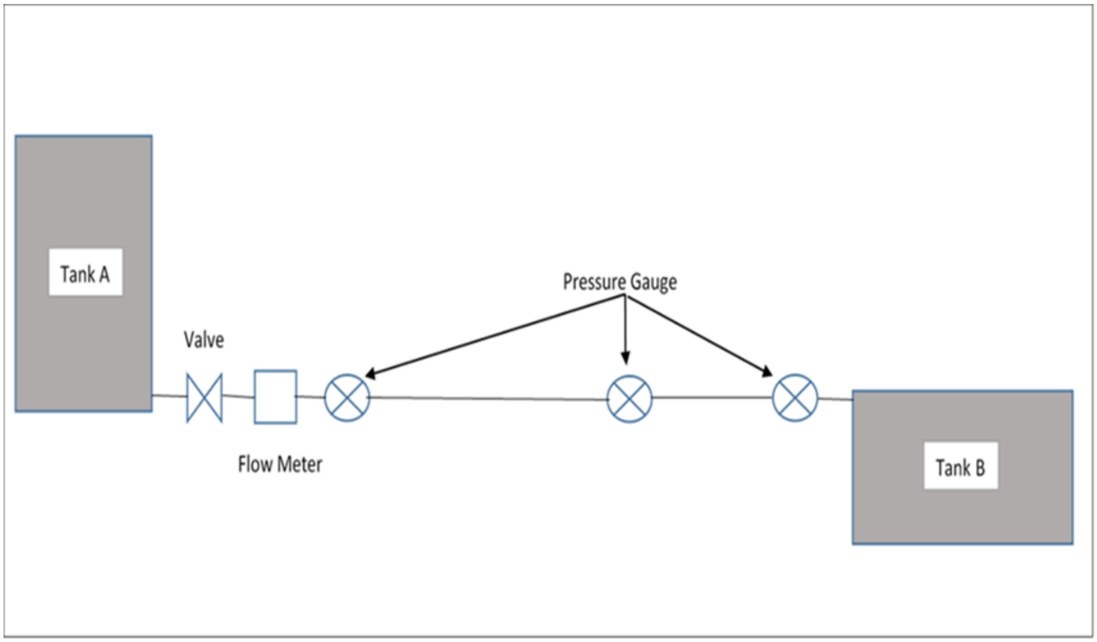


Figure(2) Kinematic viscosity measurement instrument [6].

Tools and Equipment:

A flow meter was set up to read the discharge of oil in the pipe. As it was shown in Figure (3), two more valves were connected beyond gauge 1 and gauge 3.

As it was shown in the system, three-gauge pressure were established linearly to read the pressure head in three zones including, upstream, cracked zone which is located at 140 cm and downstream. Th6ere have been different types of cracks in the last 60 cm of the pipe. The cracks were in different sizes in which started from 1cm to approximately 50cm.



Figure(3) Diagram of experimental setup.

The equipment that was installed in the Sulaimani polytechnic university in fluid laboratory which differs from the equipment shown in Figure (3) because a pump has been added for the purpose of circulation as shown in Figure (4).

Figure(4) Experiment setup the carbon steel pipe which was appropriate for transporting crude oil has been used in conducting the experiment.

The method was used to making cracks in the pipe in the current investigation welding. Making crack by welding the length of each crack case have been varied from 0.01m in case 2 and increased gradually to 0.475m in case 9. The method reviled good results because it was effective to penetrate the pipe as illustrated in Figure (5).

Figure (5) Making crack by welding the length of each crack case have been from 0.01m in case 2 and increased to 0.475m in case 9.

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action, typically converted from electrical energy into hydraulic energy. It produces the flow necessary for the development of pressure which is a function of resistance to fluid flow in the system.

As for pressure, to maintain the required head a pump was needed to be set at the discharge point right at the beginning of the pipe. The pump was necessary because the hydrostatic pressure was not enough to push the oil as the main tank height was small, Figure (6).

Figure (6) The pressure pump.

The mass flow-meter was required to measure the incoming flow of crude oil in the supply pipe for obtaining the results. The measurement of crude oil and viscous fluids requires rugged and reliable metering equipment. While high viscosity flow measurement proves to be difficult for most flow meters, Liquid Controls Positive Displacement Flow-meters provide a solution as shown in Figure (7).

Figure (7) High accuracy meter.

The pressure gauges that has been used in achieving the measured of pressure was positioned at three different zones which is including upstream, downstream and crack zone. For each experiment it was tested 3 times and the calibration was implemented before each test so that the précised data will be obtained. The gauge number 1 has read (6psi to 6.1psi) in upstream zone. The gauge number 2 has recorded (4.8 psi to 5.5 psi) which is regularly increased with the increased pressure and the 3rd gauge calibration was ranged from (4.3 psi to 4.75psi), as shown in Figure (8).

Figure (8) The gauge is used in the practical work

Boundary Conditions The present simulation is carried out to analyze the dimensions and finding out the consequences of the cracks on pressure drop of the crude oil in the modelling pipe. It is assumed that the flow is steady state, the oil is, Newtonian and incompressible. The velocity was 0.2m\s at 290k, the section area is 0.000314m2 and the pressure is 16500.4Pa. Continuity and momentum are in one direction along the pipe length, no lateral velocity. Nine cases were studied with similar boundary conditions as shown in Table 2 and different cracks.

Table 1. Cases Studies [10]

Pipe Case	Radius of the Crack (m)	Length of the Crack (m)
Case1	No Crack	No Crack
Case 2	0.0005	0.01
Case 3	0.0005	0.05
Case 4	0.0005	0.125
Case 5	0.0005	0.175
Case 6	0.0005	0.3
Case 7	0.0005	0.35
Case 8	0.0005	0.4
Case9	0.0005	0.475

RESULTS AND DISCUSSION

It has been observed from the results provided by the Figure (9) below that there are three gauges have been used in practical. The gauges are classified as upstream gauge 1, cracked zone gauge 2 and downstream gauge 3. Each gauge has different features with respect to the pressure and size of the crack. From these results it can be seen that the pressure in the upstream has a maximum value as compared to the downstream which has a minimum value while the figure for the cracked zone is fluctuating at moderate. Simultaneously, the presented results are confirming that from the upstream gauge 1 less pressure is required for pipes with no cracks, but the pressure is increasing with having cracks. While the pressure value from second and third gauge there has been a disproportional relationship between the increased crack and pressure value. In other words, the greater cracks in the pipe, the smaller value of pressure is obtained.

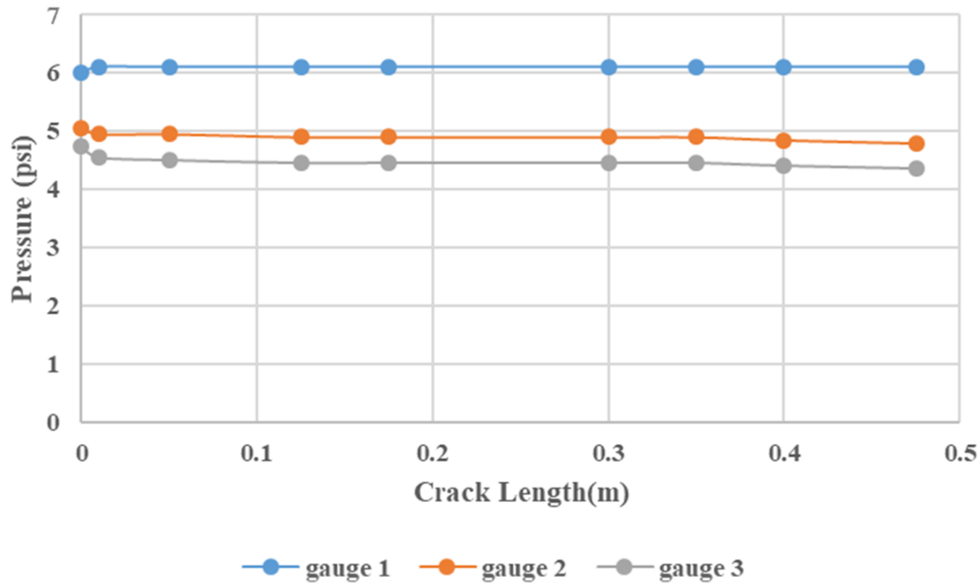


Figure (9). Pressure at different crack length

Figure (10) represents the relationship between the pressure drop and cracks lengths in. The results presented that the pressure drop in the non-cracked pipes are less than those pipes containing cracks. This interpretation is true in terms of cracked zone and downstream. Whereas, until the crack has increased in both zones the pressure drop is raising according to the obtained results from Figure (10). The pressure drop in the downstream is lesser than the cracked zone which is the objective of the current research project. Furthermore, there is no pressure drop in the upstream because the gauge is setup at the beginning of the pipe.

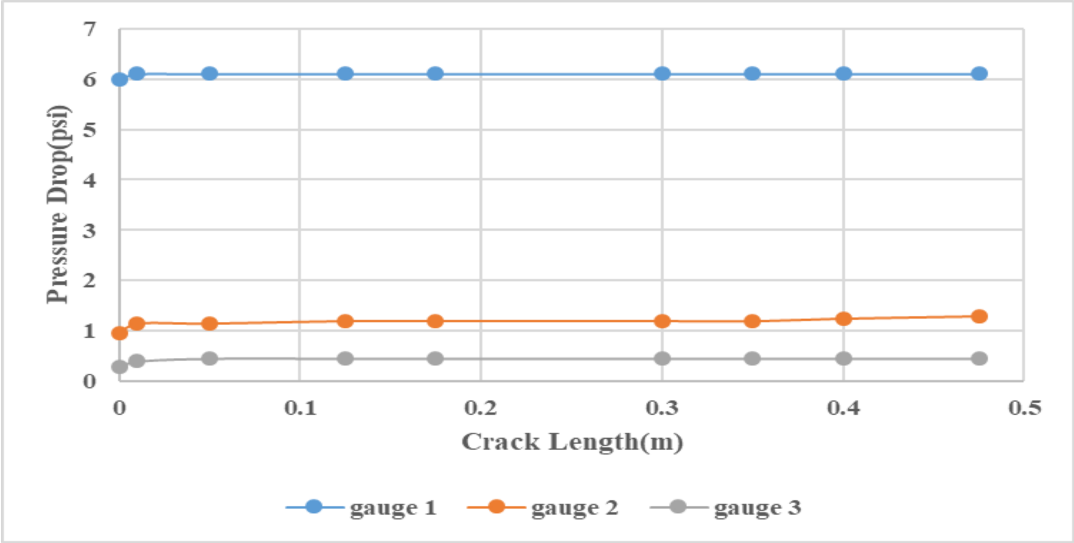


Figure (10). Differential pressure at different crack length

In Figure (11) the data is the same as the Figure (10), therefore the pressure drop is happening only in the downstream and cracked zone as shown below. The pressure drop is increasing slightly in both zones as the size of crack expands. As illustrated below, low pressure drop from gauge 2 and 3 were recorded at the beginning of the crack length however there has been a dramatic change while the flow has started.

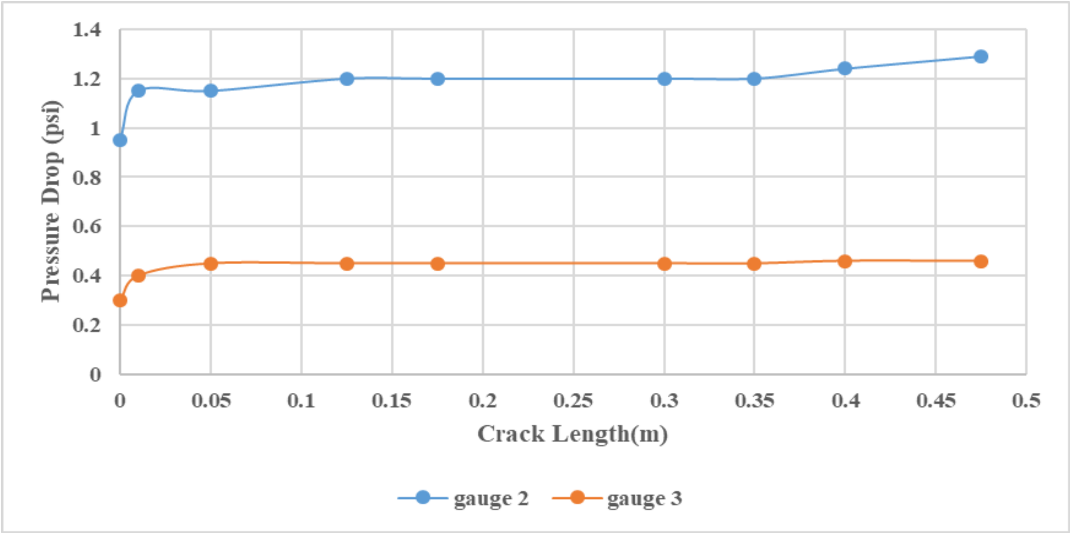


Figure (11). Differential pressure at crack and downstream zones

The results obtained from Figure (12) are completely different with the previous outcomes. It has made a comparison between the experimental and the theoretical results dimensionless at the cracked zone. It has been revealed that the results obtained by both investigations are equal in increasing the pressure drop. The pressure drop is smaller in the pipe with no-crack in comparison with the other pipes. However, the pressure drop in CFD results is less than that in the practical experimentation due to having minor losses in the built up rig such as; valves and fittings.

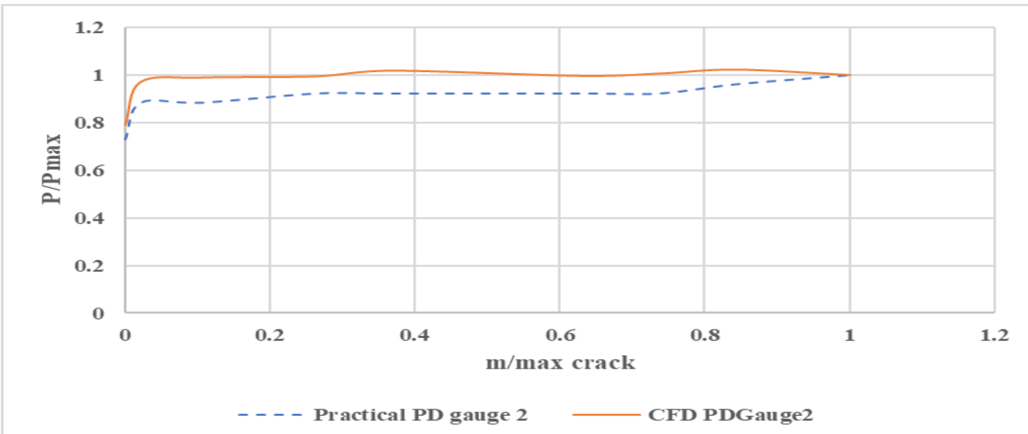


Figure (12). Comparison of theoretical with practical differential pressure (cracked zone)

The results attained in Figure (13) are similar to the Figure 8 but it represents the downstream measured and theoretical data. Similarly, the greater value of cracks is resulting in the higher value of pressure loss. The Pressure Drop in Cracked Pipelines with No Leakage 416 magnitude of pressure drop by gauge 3 is increased erratically from the small size of cracks then it has small fluctuations and finally reaches the peak value at the maximum size of crack length which is equal to 0.475m in the downstream section of the pipe. It has been observed that the obtained data are approaching from each other and they had a close relationship with a small deviation due to pressure loss produced by the joints and connections in the pipe.

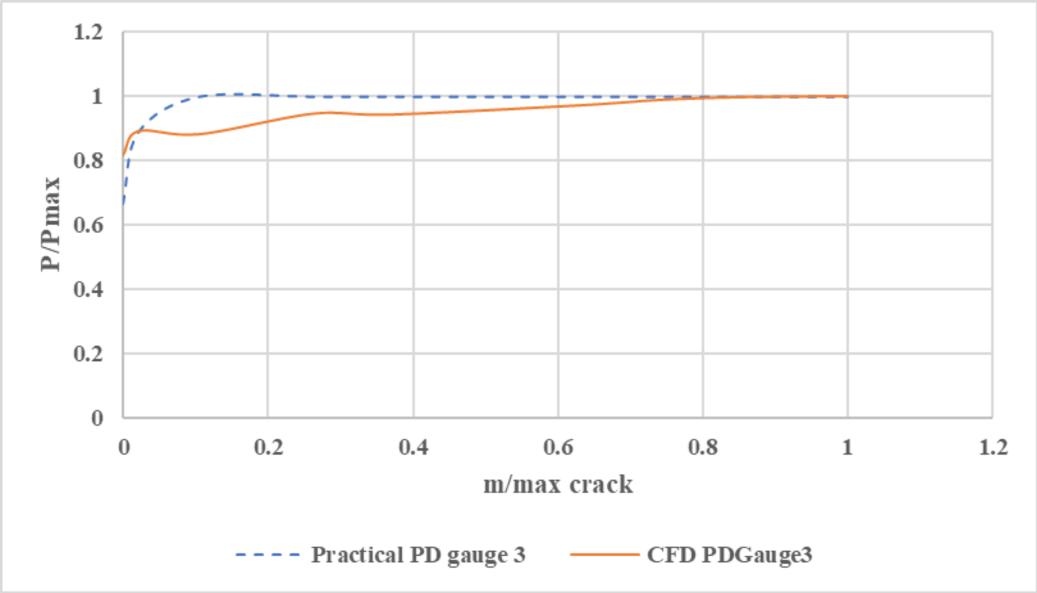


Figure (13). Comparison of theoretical with practical differential pressure (downstream)

CONCLUSION

This research highlights the probability of pressure drops in cracked pipelines. The pipeline is divided into three parts: the crack zone, and the upstream and downstream zones. Results indicate a significant pressure drop in cracked pipes, particularly in the crack zone. The study concludes that cracked pipes are unsuitable for oil transportation, as pressure losses not caused by friction or fittings might indicate cracks. The findings apply only to non-leaking cracks. Future research is recommended to investigate crude oil accumulation around cracks, which could eventually block the pipe and cause fractures or damage.

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