Simulation of Deposition Detection inside Wellbore by Photon Backscatter Radiography

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ABSTRACT

In the process of extracting oil and gas from hydrocarbon reservoirs, the formation of depositions inside pipes, fittings, and storage tanks, not only accelerates corrosion but also reduces a significant volume of operating capacities. The most critical step in solving the problem of deposition formation is their early and timely detection. In industries, internal surfaces of the pipeline are usually inspected by nondestructive testing (NDT) methods. The detection of depositions should operationally be difficult if there were special conditions for accessing the back of pipelines. Therefore, a suitable method is encouraged to detect deposition in the pipes and tubes when one side or a small part of them is accessible. In this paper, the Monte Carlo simulation tool was applied to use backscatter radiography (as an NDT inspection technique) for in-situ detection of depositions inside the metallic pipelines. In fact, the simulation process shows the correctness and efficiency of the backscatter radiography technique. It would determine some significant factors such as photon energy, angle of irradiation, or location of detectors which affect the design before experiment. The results showed that backscatter radiography as a viable technique could properly detect the location of depositions inside the pipes.

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1. INTRODUCTION

In the field of oil and gas industries, monitoring of depositions is a significant subject for preventing harmful consequences and costly damages due to flow restriction through transmission pipelines [1]. Some changes in pressure and temperature cause some physical and chemical phenomena for deposition formation when the fluids approach the earth’s surface from underground in the extraction process of hydrocarbon reservoirs [2]. Organic and inorganic (such as asphaltene, wax, hydrate, and mineral compounds) depositions commonly formed in the pipelines and equipment [3]. Asphaltene has a complex molecular structure and is the most polar composition in oil [4]. Waxes are high molecular weight and complex compounds which generally are in the solid phase at ambient temperature. Wax depositions (with normal chains of alkanes) stick on the internal pipes at low temperatures and make longer chains [5, 6]. Hydrate depositions are typically formed in gas transmission pipelines, as well. In the cold seasons, gas molecules in pipes are imprisoned and frozen in cages made from water. Plugs will block the flow path and stop gas processing during hydrate crystals formation [7].

Petroleum industries often suffer from inorganic depositions, including carbonates and sulfates [8]. These deposits are generally associated with water formed in calcium carbonate, calcium sulfate, and barium sulfate. Some deposits, such as iron sulfide and iron carbonate, may also be produced as corrosion agents [9].

Caliper Pipeline Inspection Gauge (Caliper PIG) with mechanical arms is a device that is used in fluids (such as water, oil, and gas) transfer pipes for measuring holes geometry [10].

Some methods for monitoring deposition formation or narrowing in the pipelines and equipment are radiography, ultrasonic, determination of fluid pressure in various points, thermal imaging, and the other inspection techniques [11-14]. However, there is some information about the strengths and weaknesses of
various inspection methods [15, 16] but, a predictable
technique based on the Monte Carlo simulation tool is
widely encouraged for the depositions formation location
detection and their contents determination. In this
research, the mentioned technique was carefully studied
in detail and validated.

2. METHODOLOGY

According to the radiography applications, X and γ-rays
penetrate through materials structure to find their quality
[17]. The radiography tool advantage compared with the
other methods (such as Caliper PIG) is the observation of
the visual image of pipe cross-section without demanding
mechanical arms and sticking on the internal surface of
the tube [10]. The conventional radiography is feasible
for pipes and tubes, which both sides of them are
available. The positions of radiation source on one side
and detector or film on the other side are important.
Compton scattering shows good potential for use in the
field of NDT monitoring. The backscatter radiography
based on Compton scattering has been proposed for
single-sided radiography under inspection. This type of
radiography can be applied for in-situ detection of faults
inside pipelines without demanding the back of them [15,
18]. Figure 1 illustrates the principle of the backscatter
radiography method for the detection of depositions
inside a pipeline [19].

Figure 2 shows the simulated geometry used in the
Monte Carlo N-Particle (MCNP) code. Specifications of
materials used in the simulation were extracted from
literature [5, 8, 20-25]. A mono-energetic source of
photon produced a ring-shaped sharp beam and irradiated
the inner side of the pipeline. Deposition in one area of
the pipe was defined as the thickness of wax, asphaltene,
salt, or hydrate over the internal surface of it. Simulations
were carried out several times by different photon
energies and depositions with various thicknesses,
lengths, and materials. The best results were obtained in
the counter cell with about 11 cm far from the radiation
source for the design investigated in this research.

As shown in Figure 3, the depositions can be
monitored by moving the inspection device through the
pipeline. Some scattered photons entered the detector
were counted after photons emission from source and
their interactions consideration with fluid, pipe,
deposition, and concrete behind the tube. Then, the
results were drawn as a graph versus the traveled
distance. A change in the number of photons in the log
can indicate the deposition occurrence along the pipeline.
The speed of inspection by backscatter radiography in the experiment depends on several factors. The most important parameter is the source strength or exposure rate of photon sources. The efficiency of the detectors and electronics used in the setup can have an essential role in the inspection speed, as well.

3. RESULTS AND DISCUSSION

Since there only are theoretical data on this type of research and still, no practical setup is tested, the necessary data (such as the energy of photons, angle of irradiation, and kind of photon beam) were obtained from the literature considering ALARA principle [15, 26]. The deposition should be significant when it occupies at least 20% of the pipe diameter. Figure 4 shows the results of this method for detection of CaCO₃ deposition inside a pipe with 1 cm length and 2.2 cm thickness of internal pipe diameter using 75, 200, and 660 keV photon sources. The results showed that low-energy photons could not produce good results due to passing photons through the fluid, penetration into the deposition, re-entry through the fluid, and finally, into the detector. Figures 5 and 6 show detecting asphaltene, CaCl₂, CaCO₃, CaSO₄, and wax depositions inside a pipe using 200 and 660 keV photons. All depositions had 1 cm length and 20% of internal pipeline diameter in thickness. The peaks shown in Figures 5 and 6 indicate the presence of deposition on the pipe surface. Furthermore, these figures clearly show that scattering will be increased, and more scattered photons may be detected (by a detector) when a high energy photon source is applied. The location of the deposition on the internal surface of the pipe can be found by counting backscattered photons in the detector versus distance. The difference in the number of backscattered photons in the area of deposition in comparison with the other parts of the pipeline led to some peaks. The material of the deposition area, density, and photon scattering property in the location of deposition may be different from the other internal areas of a pipeline. Figure 7 shows the results of backscatter radiography by 200 keV photons for detecting CaCO₃ depositions with various thicknesses. The deposition thickness range is 10 to 50% of the internal diameter of the pipe. The results showed that this method can detect thin depositions to prevent further problems. Figure 7 indicates the better results for thicker depositions (which are closer to the source and detector), as well.
Since hydrate depositions may be formed in gas pipelines, their depositions can also be studied. For hydrate deposition detection, the fluid inside the pipeline was assumed as natural gas. Figure 8 shows the results of hydrate deposition detection simulation inside the pipe with 1 cm length and thickness of 2.2 cm (20% of the internal diameter of the pipe) of internal pipe diameter using 200 keV and 660 keV photon sources. Figure 9 shows the results of deposition detection with a thickness range of 10 to 40% of the internal diameter of the pipe. Simulations were repeated for depositions with the same thicknesses but with different lengths. Figure 10 shows the hydrate deposition detection with a length range of 1-2.5 cm. The results showed that dimensions of peaks in photon logs were in good compatibility with depositions inside pipelines.

4. CONCLUSIONS

In the field of oil and gas production, various factors can prevent from the maximum operational volumes. One of these factors which has a remarkable effect on these industries is the formation of depositions inside the pipelines. Backscattered photon radiography can be applied as a practical and viable method for the detection of depositions inside the pipes where located in the wellbores without enough access to them or in the other positions where both sides of pipes cannot be accessible. In the current research, the Monte-Carlo tool was properly applied to simulate various depositions such as organic, inorganic, and hydrates detection (with various thicknesses, lengths, materials, and photon energies) inside the pipelines by backscattered photon radiography. Since counting scattered photons in detectors is easy, this technique can detect depositions in the early stages of their formation with reasonable accuracy. Furthermore, no mechanical movable part is requested in the structure of backscattered photon radiography, which is used for detecting depositions where are not accessible.

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Figure 8. Photon log for various photon energies along the pipe with hydrate deposition (deposition thickness=20% of internal pipe diameter and deposition length=1 cm)

Figure 9. Photon log for various deposition thicknesses of hydrate deposition (deposition thickness=10, 20, 30, and 40% of internal pipe diameter, deposition length=1 cm, and photon energy=660 keV)

Figure 10. Photon log for various deposition lengths of hydrate (deposition thickness=20% of internal pipe diameter and photon energy=660 keV)
چکیده

در استراحت نفت و گاز از مخازن هیدروکربوری، تشکیل رسوبات مختلف داخل لوله‌های انتقال آتشالا و در نهایت مخازن خامزه، به تنهایی باعث تشکیل آسیب‌های ویژه می‌گردد. تحقیقات مورد استفاده برای یافتن روش‌های عملکردی کاهش حجم رسوبات، به عنوان آنتی‌آسیب‌هایی، و به‌طور کلی به‌دست آمده از این مطالعه

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