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X-ray Computed Microtomography for the Inspection of Flexible Risers

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1. Introduction

In the context of oil production, there is a close correlation with advances in pipeline inspection technology, highlighting the importance of flexible risers. These play a fundamental role in oil transport, connecting wells to platforms through a system of pumps and injections [1,2]. However, the presence of residual gases such as CO_2 and H_2S causes degradation and fatigue of the risers, accelerating the corrosion process, and reducing their useful life. The loss of material in metallic layers results in damage that leads to the appearance of microcracks [3]. Furthermore, risers are subject to internal and external pressures, as well as intense mechanics during operations, highlighting the need for continuous monitoring and maintenance [4,5].

Flexible risers are made up of overlapping multilayers that consist of two fundamental elements: polymeric barriers, which protect against failures and corrosion, and prevent friction between the metal layers; and metallic barriers, which provide the mechanical properties of the risers, providing flexibility and ensuring support for internal and external pressure [6]. The metallic parts that make up these structures are the internal layer – the interlocked carcass, that transports the internal product; the pressure armor layer; and the tensile armor layers, which ensure resistance to existing loads [4,5]. Despite the functional independence of each layer, the project is designed to promote interaction between them. The purpose is to ensure that each layer is fit for purpose to meet requirements in the field [1].

Analysis indicates that the main origin of failures in flexible risers is related to the rupture of wires in the tensile armor layers. Marks and elevations resulting from the manufacturing process have the potential to initiate the formation of cracks in the tensile armor wires, causing serious fracture mechanics problems. The breakage of these wires triggers the rebalancing of loads, causing friction between the intact wires and generating structural fragility, resulting in progressive failure due to fatigue [6]. Therefore, constant monitoring of the layers throughout the useful life of the riser is essential to ensure safety and identify failures as early as possible to avoid irreparable damage [1].

Non-destructive testing (NDT) techniques such as fiber optics, acoustic transmission, electromagnetism, radiography, and others, are applied to the inspection and monitoring of risers, in addition to a combination of techniques that can increase the representativeness of the methods. Most techniques are intrusive or are not considered sensitive methods in different regions of the riser structures, or some limitations prevent development for field application [7]. X-ray Computed Microtomography (microCT) is a non-invasive technique, based on the X-ray attenuation process, which promotes the formation of high-resolution 3D images, allowing the visualization and analysis of the internal structures of the studied sample [8,9].

This work aims to evaluate the effectiveness of the X-ray Computed Microtomography technique in detecting defects such as microcracks in flexible risers, focusing on the structural integrity and reliability of the offshore oil and gas system.

2. Methodology

In this study, a section of the flexible riser, 440 mm in length and 155 mm in external diameter, taken from the production area, was scanned in a microtomography system. The microtomography system, Phoenix V|tome|x M, has integrated control between X-rays, detector, and sample manipulation, allowing highquality configurations when scanning images. The system has a high power microfocus tube, with a voltage of up to 300 kV at a maximum power of 500 W, and a stable digital detector, GE PXR250RT, with a pixel size of 200 µm and 2024 x 2024 pixel matrix.

The riser section was rotated in the system by 360 degrees, in analogous angular steps, and image acquisitions were optimized as shown in Table I. After acquisitions, the images were reconstructed and analyzed using appropriate softwares.

Table I: Acquisition Settings

Microtomography System	Phoenix V|tomex|m
Voltage (kV)	260
Current (µA)	340
Acquisition Time (ms)	500
Projections	1200
Effective Pixel Size (µm)	113.8
System Rotation	360°

3. Results and Discussion

The 2D image obtained by microCT shows the metallic layers of the riser, where defects are evident in their innermost layer – interlocked carcass –, the smallest being on the order of 0.268 mm. Fig. 1 shows the interlocked carcass with defects measured and shows the pressure armor layer.

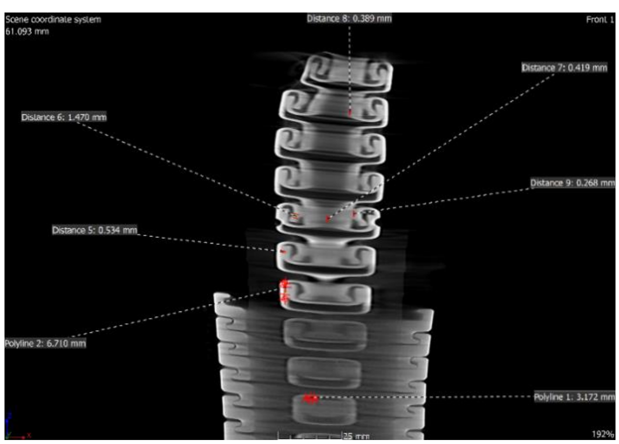

Figure 1: MicroCT 2D Image –defects in the internal layer and the pressure armor layer.

In Fig. 2, the 3D image obtained by the microCT process shows all the structural layers that make up the riser – from the external to the internal part, it is noted: the interlocked carcass, the pressure armor layer, and the internal and external tensile armor layers.

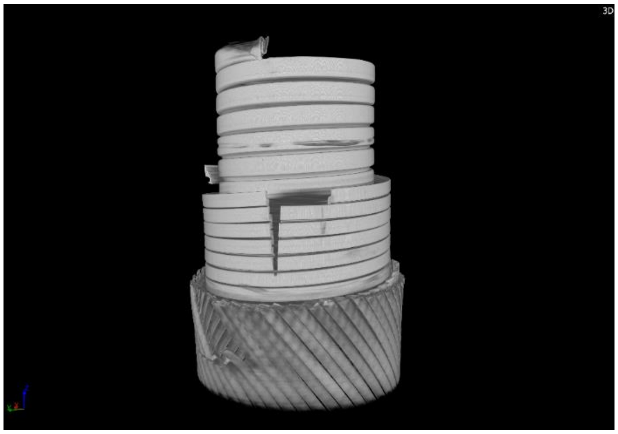

Figure 2: MicroCT Image - 3D model of the flexible riser layers

To identify each layer of the riser separately, the image segmentation process was applied. During the analysis, defects were identified in all layers of the riser. In Fig. 3, defects can be visualized and measured on a color scale ranging from 0 mm to 2 mm.

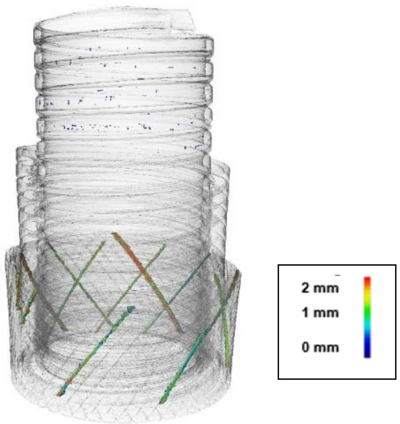

Figure 3: MicroCT Image - segmentation process and visualization of defects in the metal layers.

The images obtained using the microCT technique revealed the presence of defects in all layers of the riser. Notably, the interlocked carcass presented the highest number of defects and the smallest dimensions. Considering that this layer constitutes the internal region of the riser, the effectiveness of the technique was demonstrated.

4. Conclusions

The application of the X-ray Computed Microtomography Technique shows to be a promising approach to inspect the metallic layers of flexible risers. Through the image segmentation process, the different layers of the riser could be identified and analyzed separately. The results revealed the presence of defects in all layers of the riser, with the smallest being found in the interlocked carcass, reaching the order of 0.268 mm. The images generated by microCT enabled satisfactory results to be found, showing the effectiveness of the technique in non-destructive inspection in detecting defects.

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