Measurement 127 (2018) 15–20

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Experimental research on the precision of wheeled caliper arm for measuring pipeline deformation

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ARTICLE INFO

Keywords:
Pipeline inspection
Geometry pig
Wheeled caliper arm
Deformation
Accuracy

ABSTRACT

Wheeled type caliper is a half way pig between utility and intelligent pig. It is designed to efficient detect, size and locate deformations of the pipeline. Mapping the pipeline can also be achieved with the integration of triaxial accelerometer and gyroscope. In this paper, the wheeled caliper arm was designed and experimental research on the precision of the wheeled caliper arm was conducted to evaluate its performance. The effects of the deformation size, the spring pre-tightening force and the pigging velocity on the precision of the wheeled caliper are investigated. Experimental results indicate that the precision of the caliper can be greatly affected by the pigging velocity and the pre-tightening force. High pigging velocity has large contribution on the increment of the measurement error. However, the error can be reduced or even eliminated by increasing the pre-tightening force. Experimental results can provide guidance for the reasonable selecting of the pigging velocity, and the pre-tightening force to provide enough contact force.

0. Introduction

For decades, oil and gas industry has used pipelines as the most economic and efficient way to deliver oil and gas to terminals. However, the long usage time has raised great concerns regarding the safety conditions of aging pipelines. Periodical pigging of these pipelines is recognized as the most cost-effective method to enhance pipeline safety and integrity while the pipelines are in service [1–9].

There are different types of pigs. Pigs can be classified by their maintenance aim from the simplest foam pig to the most complex intelligent pig. Utility pigs can perform a function such as cleaning, separating products in-line or dewatering the line; Geometry pigs are used to check the geometry and location of a pipeline for the configuration and mapping; Intelligent pigs or smart pigs can deliver the detailed information about a pipeline, such as pipe wall defects, cracks, corrosion, etc. [10–12].

Caliper, as a kind of geometry pig, is a halfway device between utility and intelligent pig. It is designed to effectively detect, size and locate deformations that can affect pipeline integrity or impede the passage of other tools. Mapping the pipeline can also be achieved with the integration of triaxial accelerometer and gyroscope.

Till now, the most common caliper pigs can be divided into three categories according to the structure of their detector arms: wheel-type caliper (wheeled caliper), rod-type caliper and probe-type caliper [13]. Among these caliper pigs, wheeled caliper is widely used as there is almost no scratches damaged on the pipeline inner wall after operation. In addition, the rolling movement between the wheeled caliper arm and the pipeline results in a relative smaller amount of wear, compared with the sliding movement of rod-type caliper and probe-type caliper arm. As a result, the inspection precision of the wheeled caliper is more stable during a long distance working. However, literature review indicates that qualitative analysis on the performance of wheeled caliper is scarcely found. Kim. B.D. developed a geometry pig analysis software to offer multiple views for visualizing finger data, which contributes to the high precision of the analysis results obtained from caliper pig [14]. Kim. D.K. developed a wheeled caliper, with high resolution, low power consumption and rapid response property. Experimental research was conducted to estimate the accuracy of the caliper system and it is about 1 mm [15]. Li designed an inspecting system to simulate the movement of the probe-type caliper arm sweeping across a convex defect. Experimental results indicate that the inspection precision are determined by the speed and spring pre-tightening force [16].

In this paper, A wheeled caliper arm was designed and experimental research on the precision of the wheeled caliper arm was conducted to evaluate its performance. The effects of the deformation size, the spring pre-tightening force and the pigging velocity on the precision of the wheeled caliper has been investigated. Proper spring pre-tightening force was finally suggested for reducing the relative error of this kind of

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https://doi.org/10.1016/j.measurement.2018.05.093
Received 26 January 2016; Received in revised form 15 May 2018; Accepted 23 May 2018
Available online 26 May 2018

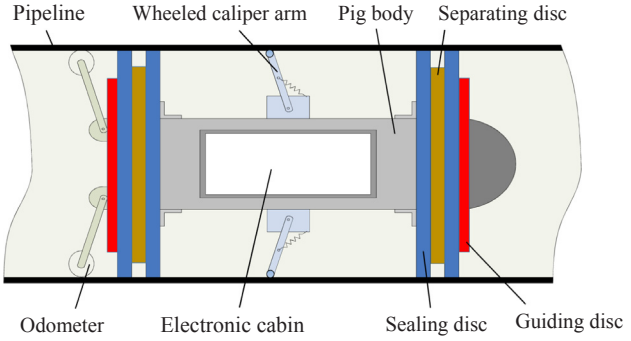


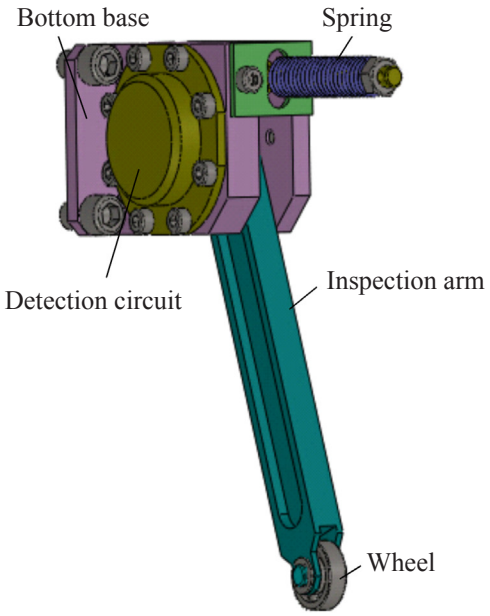
Fig. 1. Schematic diagram of caliper pig in the pipeline.

caliper arm.

1. Structure of wheeled caliper arm

The caliper arms are usually uniformly distributed in the circumferential direction of a pig body, as shown in Fig. 1, and the numbers of these arm determine the resolution of the inspection. Sealing discs, separating discs and guiding discs are randomly used according to the pipeline inner condition. The power supply and the data acquisition system are sealed in the electronic cabin. Cooperated with the odometer system, pipeline deformation can be measured and located after the data processing.

The structure of the wheeled caliper arm is shown Fig. 2, it consists of wheel, inspection arm, spring, detection circuit, bottom base, etc. Spring can provide inspection arm the force against the pipeline. Detection circuit consists of two main components. *The first is a permanent magnet built into a shaft inside the inspection arm. The second is a detection circuit (AS5045 from ams AG company, Australia) placed on the bottom base.* The relative movement between the caliper arm and the pipeline can be transferred to the relative movement of the permanent magnet and the detection circuit. As a result, different voltage can be detected, corresponding to different rotation angle. Once the rotation angle of a caliper arm was captured, the size of the deformation can be computed according to the geometric equation.



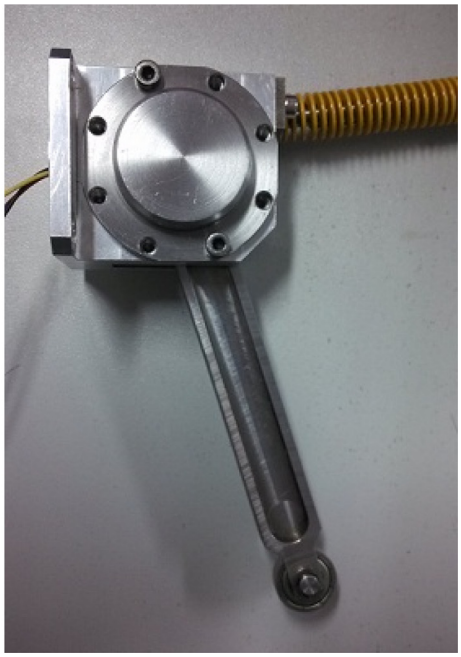


Fig. 2. Schematic diagram and porotype of the wheeled caliper arm.

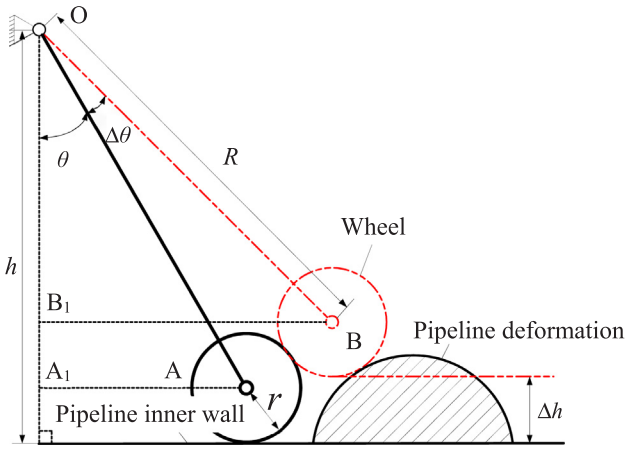


Fig. 3. Geometry model of the wheeled caliper arm passing over the pipeline deformation.

2. Geometry model of wheeled caliper arm

As shown in Fig. 3, when there is no pipeline deformation, caliper arm maintains at the position of OA during pigging, and the wheel contacts with the pipeline inner wall tightly. The angle between the inspection arm and the normal of pipeline deformation is θ. Once the caliper arm comes across the pipeline deformation, the angle will experience an increment. For example, at the position OB, the increased angle is Δθ. As a result, the following equations can be obtained.

$$R\cdot\cos\theta + r = h \tag{1}$$

$$R\cdot\cos\theta - R\cdot\cos(\theta + \Delta\theta) = \Delta h \tag{2}$$

where R is the length of the caliper arm, r is the radius of the wheel, h is the distance from the fix point O to the pipeline inner wall, Δh is the inspected height of the pipeline deformation.

According to the Eqs. (1) and (2), the height of the pipeline deformation (Δh) can be computed, and the geometry of the deformation can be sized with the effort of the odometer, for measuring the caliper's axial distance.