# Recent Developments in Speed Control System of Pipeline PIGs for Deepwater Pipeline Applications

Mohamad Azmi Haniffa, Fakhruldin Mohd Hashim



***Abstract*****—**Pipeline infrastructures normally represent high cost of investment and the pipeline must be free from risks that could cause environmental hazard and potential threats to personnel safety. Pipeline integrity such monitoring and management become very crucial to provide unimpeded transportation and avoiding unnecessary production deferment. Thus proper cleaning and inspection is the key to safe and reliable pipeline operation and plays an important role in pipeline integrity management program and has become a standard industry procedure. In view of this, understanding the motion (dynamic behavior), prediction and control of the PIG speed is important in executing pigging operation as it offers significant benefits, such as estimating PIG arrival time at receiving station, planning for suitable pigging operation, and improves efficiency of pigging tasks. The objective of this paper is to review recent developments in speed control system of pipeline PIGs. The review carried out would serve as an industrial application in a form of quick reference of recent developments in pipeline PIG speed control system, and further initiate others to add-in/update the list in the future leading to knowledge based data, and would attract active interest of others to share their view points.

***Keywords*****—**Pipeline Inspection Gauge (PIG), In Line Inspection Tools (ILI), PIG motion, PIG speed control system

## I. Introduction

PIPELINES are used worldwide in various kinds of product transportation and most commonly used in the petroleum industries. Overtime, the pipeline will deposit debris or residual products such as scale, wax, and gas hydrate as well as exposed to physical damages such as dent and internal corrosion. Utilization of pigging as a common practice has become a standard industry procedure to deal with these emerging challenges. For effective operation, the pipelines have to be maintained periodically through cleaning and inspection. This is done by means of a special device called Pipeline Inspection Gauge (PIG) or conventional pig and In-line Inspection tools (ILI) or intelligent PIGs. The former is for cleaning, while the latter is for physical condition inspection, for both applications, require insertion of the device into the pipeline, via the pumped fluid (gas or liquid) upstream the device to provide required force and set the device in motion in order to execute the task.

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The speed control of PIGs in oil pipelines with its inherent liquid characteristic of incompressible, lubricative, and cushioning allow easier speed control. In gas pipelines the speed control becomes more crucial and important due to compressibility, absence of lubricative, cushioning features and association with velocity excursion. Realizing the importance of pipeline PIGs motion behavior, in the last decades, papers [1-14] have been evident for efforts carried out to understand it better. However, the efficiency of cleaning and inspection actions are greatly dependant of the PIG speed which is further influenced by several parameters such as flow rate, operation pressure, and pipeline geometry. Regardless of whatever the pigging target, the PIGs are most effective in performing their intended function when they are operated at a near constant speed [3, 4, 6, 8, 9, 10]. Moreover, excessive and uncontrolled speed of a PIG can be very dangerous such as bursting of pipeline due to PIG stuck. In view of this, understanding the motion (dynamic behavior), prediction and control of the PIG speed is important in executing pigging operation as it offers significant benefits, such as; estimating PIG arrival time at receiving station, planning for suitable pigging operation, and improves efficiency of pigging tasks. To date, several papers have discussed the speed control systems for pipeline PIGs.

## II. Past and Present Development in Pipeline PIGs Speed Control Systems

The speed control methods can be either active or passive. In passive speed control methods [5,11], the strategy would be to control the PIG speed via externally generated controls such as controlling the operating pressure or flow rate which would result in slowing down / increasing the speed of PIG. In active speed control [3, 8, 14, 15-23], the travelling speed of the PIG in the pipeline is controlled by its own incorporated mechanisms. The stable speed depends on the drive mechanism efficiency. The final output of a drive mechanism can be either varying speed or constant speed. The literature survey reveals that very few works done [14, 17, 21], which succeeded in achieving constant speed control of pipeline PIG. Similarly, for bidirectional pipeline PIG [19, 20, 23].

TABLE I
SUMMARY OF PAST AND PRESENT DEVELOPMENTS OF PIPELINE PIG SPEED CONTROL SYSTEMS

| Researchers | Principle | Unidirectional / Bi-Directional flow | Active Or Passive Speed Control | Characteristic of speed |
|---|---|---|---|---|
| E. Appleton and N.W. Stutchbury [15] | Traction is obtained by the reciprocating motion of two cylindrical brushes of a diameter larger than the pipe bore. The brushes move forwards down the pipe but grip the pipe wall to resist backward translation. | Unidirectional | Active Speed Control | Varying Speed |
| T.T. Nguyen et. al. [3] | Nonlinear control method, control of pig using the amount of bypass flow across its body | Unidirectional | Active Speed Control | Varying Speed |
| L. A. Dykhno et. al. [5] | By providing sufficient fluid pressure to propel the PIGs | Unidirectional | Passive Speed Control | Varying Speed |
| Carl R Torres Jr. et. al. [16] | Venturi-shaped through passages extending longitudinally permitting fluid within the pipeline to bypass the PIG | Unidirectional | Active Speed Control | Varying Speed |
| Uwe Thuenemann et. al. [17] | Based on speed information provided by the odometer system, a control valve opens the bypass as required, thereby regulating the speed of the inspection tool. | Unidirectional | Active Speed Control | Constant Speed |
| Zhelong Wang and Hong Gu [18] | Self-driven bristle based traction motion using pneumatic cylinder | Unidirectional | Active Speed Control | Varying Speed |
| Susan D'Arcy [19] | The fluid is channelled into the turbine by a shroud to locally increase the fluid velocity in order to generate power, transmitted to the gearbox / traction drive shaft via a magnetic coupling. | Bi-directional | Active Speed Control | Varying Speed |
| Z. Hu and E. Appleton [20] | Self-driven crawling operation based on unique characteristics of bristle (two sets of bristle with reciprocation motion towards and away from each other. | Bi-directional | Active Speed Control | Varying Speed |
| F. Esmaeilzadeh et. al. [11] | Flowrate of pipeline is used to control PIG velocity. | Unidirectional | Passive Speed Control | Varying Speed |
| B. Stoltze [21] | The brake constitutes a defined counter force to adapt to any pressure change of the driving force to maintain constant speed | Unidirectional | Active Speed Control | Constant Speed |
| S.T. Tolmasquim et. al. [11] | Maintaining maximum and minimum fluid pressure in the pipeline within stipulated limits | Unidirectional | Passive Speed Control | Varying Speed |
| Jian-Yong Li et. al.[14] | Control system using dual closed-loop control(speed and pressure) | Unidirectional | Active Speed Control | Constant Speed |
| Ding Feng et. al. [22] | Flowing media enables impeller drive the electric generator to generate power to charge the batter installed in the robot to change gear speed | Unidirectional | Active Speed Control | Varying Speed |
| Qinxue Pan et. al. [23] | Control of swimming and rotating motion of robot by applying external alternating magnetic field in pipe | Bi-directional | Active Speed Control | Varying Speed |

## III. ASSESSMENT OF THE PIG SPEED CONTROL SYSTEMS

Most of the studies undertaken in the past and even at present have focused their interest in incorporating an active speed control which enables a pipeline PIG to travel at desired speed. In this respect, active speed control system acquires its speed control via self mechanism which generates its own speed. Such mechanism is vital as it minimizes or eliminates the influence of pipeline operation parameters' fluctuation. This is important for pipeline PIG as it ensures that travelling speed is always maintained within limit even when the flow rate and pressure in the pipeline changes [17], unlike the passive one, which is heavily influenced by these changes. Controlling of pipeline operating pressure, manifold pressure, and flow rate, are examples of passive control system. These factors usually are very much dependable on pipeline systems' operating condition and are prone to fluctuation due to various reasons. In relation to this, most of the studies carried out resulted in varying speed control, with the exception of several works in achieving constant speed [14, 17, 21].

## IV. SIGNIFICANCE OF THE PIG SPEED CONTROL

ILI tools without speed control tool requires 1-2 km (1.6-3.2 miles) of travel before reaching the desired speed [24]. With speed control, it achieves the target speed within only 0.050 km (0.03miles).

As PIG is most effective for whatever the intended functions when it runs at a near constant speed, efficient speed control will enhance the results of cleaning, inspection, and mapping of geometries within pipeline.

Excessive and uncontrolled speed of a PIG can be very dangerous and incurs additional operational costs. PIGs possessing features such as, bidirectional movement, capable of achieving constant speed with active speed control mechanism, and self-propelled eliminates the need for tethered power supply which has limitation in power storage with travelling distance inside pipeline.

Detection provides condition of pipeline deformities which is crucial for pipeline operators to undertake corrective actions effectively as to avoid any pipeline severities.

The key to reliable and with high quality data are directly influenced by the tool speed. Liquid lines with its incompressibility and lubricative features are capable in avoiding velocity spike, unlike in gas lines, which are prone to experience velocity surge / excursion due to its compressibility. Hence it would be considerably important to establish a continual development of speed control essentially in gas pipelines.

## V. CONCLUSION

The recent development of pipeline PIG speed control system clearly indicates that it is paramount to have efficient speed control and to have the tools running either for cleaning or inspection at a constant speed. This is very crucial especially for ILI tools for accurate data acquisition. Otherwise, it would impair its performance which could diminish the integrity of the pipeline condition. Furthermore, it has become evident for the growing demand for higher accuracy of anomalies characterization and detection in ILI industry to cope with the challenging environment of deepwater regions of which are increasingly becoming hotspot petroleum exploration industries to have overall efficiencies. The review carried out would serve as an industrial application in a form of a quick reference of recent developments in pipeline PIG speed control system, shall initiate others to add-in/update the list in the future leading to knowledge based data, and would attract active interest of others to share their view points.

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