AUTOMATED SYSTEM FOR REFORMATION OF PIPELINES PLAN

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ABSTRACT

This paper deals with automation of oil pipelines inspection by means of pig. The methods of pig location and navigation have been examined. The experience of aerospace technologies for construction of inertial system of navigation is used. The original method of inertial system correction has been proposed. The block diagram of algorithm for automated data processing of pipelines inspection and reconstruction of their plan is developed.

I. INTRODUCTION

The pipeline industry has done an excellent job in designing, constructing, and operating pipelines to assure their safe operation as well as the safety of the public. But as well as any technical systems, pipelines can lose its function. It is estimated that over %60 of the pipelines in the IRAN are over 30 years old. In reviewing the incident statistics we find that for natural gas transmission and gathering pipelines, for a 10 years period the average number of incidents reported was 390 with property damage cost of $ 50/000/000 [1].

For the reduction of the above-mentioned losses it is necessary to carry out periodic inspection of pipelines and eliminate released damages at early stages of evolution. The special tool for the decision of this problem is “pig”. A pig is defined as “A device that moves through the inside of a pipeline for the purpose of cleaning, dimensioning, or inspecting”.

In an instantaneous way, the device carries out the diagnosis of the physical condition of a pipe. Among other data it is very important to know the location of this device during its movement and so the position of damage in the pipe, which has to be determined. Nowadays, different types of pigs for pipelines monitoring are used [2].

Intelligent pig was designed to deliver detailed information about a pipeline. Pig has very complicated navigation system. Some pipeline obstructions are unavoidable, and are indeed a part of the jobs. Road and building construction near pipelines put them in danger of being struck and dented by heavy machinery. The incident summary by cause for gas Transmission and gathering pipelines for 2002 is fairly consistent with previous years.

The leading cause being damage from outside force at %50 [1]. Soil erosion and Traffic vibration can cause sags, buckles and oval ties. Because there are all dynamic situations changing on a daily basis, one cannot predict whether a pig will make it through the line. Pipeline companies are feeling pressure from many sources to perform ever more thorough and detailed examinations of their systems. Toward this end, extensive pigging of all kinds is becoming an increasingly common activity world wide, and an increasingly basic part of this pigging is the easy and accurate pig location and tracking.

There are active and passive methods of pipeline pig location and tracking such as: acoustic, mechanical, radioactive, sonic and active magnetic, but these methods have one important lack. That is, for determining the pig location the operator with the receiver has to be located above of it.

II. SUGGESTED SOLUTION

There are few systems to determine the pig location. The bases of these systems are the inertial navigation system that is of the same type used in aerospace industry. The opportunity on the application of space-born technologies in petroleum industry has occurred due to appearance of a new generation of inertial sensors, on board computers and electronic memory [3, 6].

Further more, it has been used angular speed and acceleration sensors to determine the pig attitude, as well as the inclination and directions angles of a pipe. Three basic advantages of these sensors allow applying them to determinate the pig site. Firstly, these sensors have small sizes permitting the system design with the sizes those are less than the minimum diameter of a pipe of about 6 inches. Secondly, they have small power consumption. This is an important point because when a pig moves inside a pipe, it consumes the electric power only from an independent accumulator. The speed movements of a pig could vary from 2 up to 8 m/sec, and the distance of the control could be up to 500 kilometers, that needs up to 3 days running along the way. Therefore it is very important that sensors do not consume so much electric power. Third, and may be the most important advantage of these sensor is their high accuracy and small drift. These three advantages make possible to design the independent navigation system to work for a long time without melding of any correction.

The methods for positioning of the pig have been proposed in this paper. These methods are related with such sensors pendulous and potentiometers and give independent information about the angles that we use to improve the final position data.

III. SYSTEM STRUCTURE

It is very important to optimize the division of data processing between onboard and ground computers for design of this type automated system. Also it is necessary to be guided by principles of the minimum sufficiency and take into account the accuracy of the maintenance [4].

Because the basic part of data processing would be carried out at the laboratory, it is necessary to write down the sensor information to the electronic memory. For instance if the pig traveled a distance about 100 kilometers with a average speed about 2 m/sec. During a time about 5×10^4 sec. With minimum radius of pipe about 150 mm and the maximum radius of pipe bend is equal to 4 diameters, the length of the arch is 90 degrees would be about 95 deg/sec.

To perform the data recording with accuracy about 0.01 deg/sec, it is necessary to use the frequency about to 10 kHz. Thus, the memory volume to record only one parameter has to be about 950 GB. Practically it is inexpedient to have the onboard memory of such volumes, because it would be necessary to increase the equipment volume. Besides, it would cause the growth of the power supply. The computer summarizes the current angles magnitude with its initial size and writes down in memory not with frequency of calculation, but much less.

To minimize the volume, weight and expenses of the different parts of the pig. It is important to divide the procedures of the data processing between the onboard computer and laboratory equipment with the best rationality.

To construct the pipeline plan we need to have information about the distance and slop angle [5]

In the proposed method the distance can be measured by means of use two ways:

- With help of an odometer
- By integration of the acceleration measured during of the experiments.

The slope angles of the pipeline can be measured by means of:

- Two potentiometers, installed on both axes of cardan joint that combines two part of the pig.
- Four odometers, those are installed equally perpendicular
- Inertial/system (three rate gyros and two accelerometers) that integrates the angle speeds.

In the case of the potentiometers the system can directly measure the slope angles. It is one type of angle information.

In the second case (odometers), the measurements can be realized because an internal and external walls of the pipe have different length when pipeline has turn.

In the third case we have the standard inertial system.

In all cases, because a pig can roll about this horizontal axis, it is necessary to know the turn angles ϕ. So to measure the roll, we have proposed to use the inclinometers. Another possibility to measure a pith angle (θ) is to use the inclinometer inside the pendulum. In this case the axis of the rotation of the pendulum has to be congruent with the longitudinal axis of the pig.

Data correction can be accomplished with the help of a reference stations. So, during the experiment, for every 5 or 6 km, above the pipeline it is necessary to install the reference station. The real coordinates of the reference point are defined by means of Global positioning system (QPS) working in the differential mode before the test. This station consists from electronic location system to fix the time when pig passes underground.

The block diagram of the proposed algorithm is presented in the Fig. 1, where: θ_i , ϕ_i are pith, yaw and roll angles; L is distance; λ and φ are longitude and latitude; the very known strap down concept [3] can be realized in form of essentially a complementary filter, in which the primary measurements are the three angular rates P, Q and R and the aiding measurements are the two perpendicular acceleration measurements a_{xm}, and a_{ym}.

The algorithm is based on the Euler differential equations the equations (1) present the relation between the Euler angle rates $\dot{\phi}$, $\dot{\theta}$ and $\dot{\psi}$ to the angular rates P, Q and R measured by body – mounted rate gyros concerning inertial space.

$$\begin{aligned} \dot{\phi} &= P + Q\sin\phi\tan\theta + R\cos\phi\tan\theta \\ \dot{\theta} &= Q\cos\phi - R\sin\phi \\ \dot{\psi} &= Q(\sin\phi/\cos\theta) + R(\cos\phi/\cos\theta) \end{aligned} \tag{1}$$

The integration of the values $\dot{\phi}$, $\dot{\theta}$ and $\dot{\psi}$ would yield the computed Euler angles ψ, θ and ϕ, which clearly are referred to inertial space. These, however, would accumulate errors due to the rotation of Earth, the motion of the vehicle, and gyro drifts.

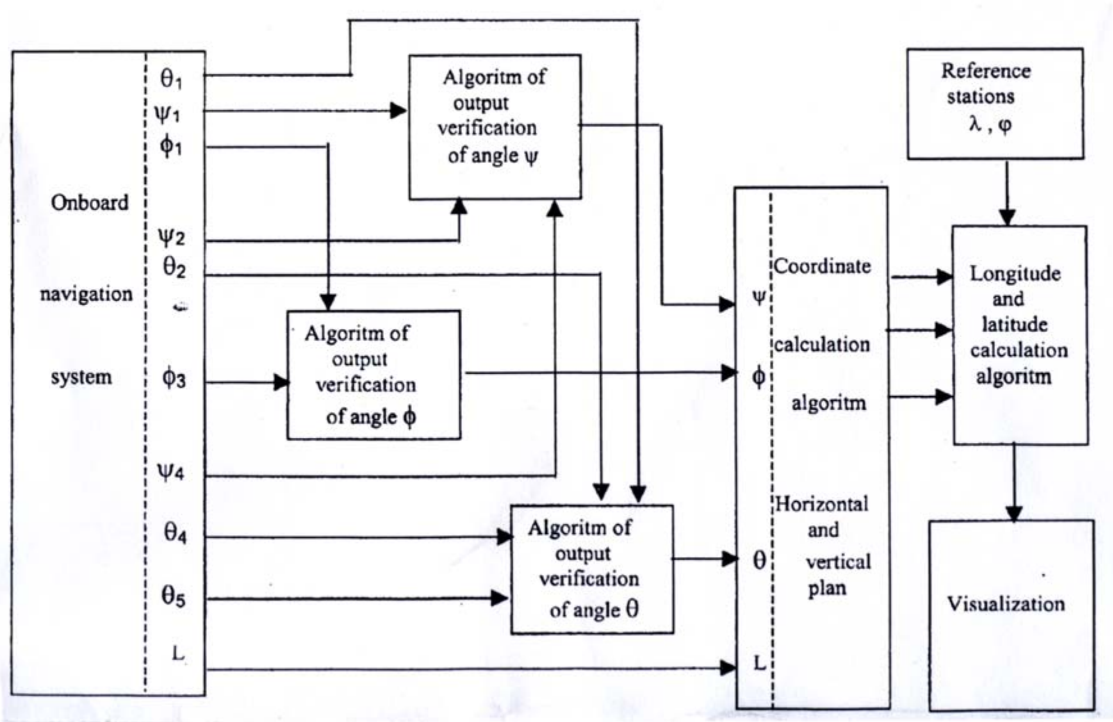

Fig. 1: The block diagram of the pipeline plan construction algorithm

The correction of inertial system can be carried out with the help of angles calculated from potentiometer and odometers systems. The two potentiometers installed on both axes of cardan joint that combines two parts of the pig and can directly measure the pitch and yaw angles. The principle of work is presented in Fig 2.

The four odometers are installed equally perpendicular.

In this case the measurements can be realized because the internal and external walls of the pipeline have different length when the pipeline has turn.

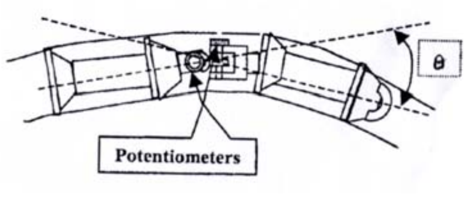

Fig. 2: principle of angles measurement by means of potentiometers

If the roll angle ϕ in not equal 0 it is necessary to determine it and to apply coordinates transformations.

The roll angle ϕ is possible to obtain by means of other method with used inclinometers (pendulums) as sensors (3,6). Physically, the range of the sensors manufactured in industry is $\pm 90^\circ$. Also, each sensor has output signal in sine form. In the area $+90^\circ$ to 270° the magnitude of out put voltages of the sensor is the same that in the area $\pm 90^\circ$. There fore it is necessary to determine in witch area works this sensor and after to take the magnitude of it as true. For this aim it is necessary to give an axial displacement between two sensors. The optimum axial displacement between two pendulums ϕ_1 and ϕ_2 is 60°. In this case calculation algorithm of the angle has such form:

If $0 \le \phi_1 \le 90$ and $\phi_2 \le 0$, then $\phi = \phi_1$

Otherwise if $0 \le \phi_1 \le 90^\circ$ and $0 \le \phi_2 \le 60^\circ$ (For range $\dot{\theta} - 60^\circ$) Then $\phi = 60^\circ + \phi_2$. for range $60^\circ - 120^\circ$, $\phi = 120^\circ + \phi_2$

Otherwise $\phi = 180^\circ - \phi_1$ (from range $120^\circ - 180^\circ$)

If $\phi_1 < 0$ and $60^\circ < \phi_2 \le -60^\circ$ then $\phi = -(120^\circ + \phi)$ (For range -$180^\circ - 60^\circ$)

Otherwise $\phi = \phi_1$ (for range -$60^\circ - 0^\circ$)

The advantage of this algorithm is used practically linear zones of each sensor.

IV. EXPERIMENTS RESULTS

A series of tests have been made in the below conditions.

Pipe line nominal diameter 36 inch
Speed working range 0.5 – 4 m/sec
Min possible bends 1.5D at 90°
Working pressure range 0.5 – 10Mpa
Temperature range $0^{\circ c} - 50^{\circ c}$

Detected defects and features

- Metal loss defects caused by jags
- Defects under repair sleeve
- Manufactures defects
- Welded joints
- Abnormal welded joints including cracks
- Deuce with adjacent cracks
- Construction defects
- Nominal wall thickness deviations

We find 2446 metal loss defects as shown in the following table:

Depth	All	Internal	External
0%-9%	2045	1404	641
10%-19%	276	-------	276
20%-29%	118	1	117
30%-39%	7	-------	7
total	2446	1405	1041

V. CONCLUSIONS

The described system to automated data processing of pipeline inspection and construction of their plans allows considerably decreasing of the expenses on the diagnosis and service of oil pipelines.

The developed algorithm to calculate of an angular estimation on the base of redundant angular data allows by means of use the additional algorithmic procedures to apply the sensors with more large algorithmic procedures to apply the sensors with more large drift.

Simulation and analysis of the results of different experimental tests with sensors have shown that the proposed and analyzed navigation method, sensors and algorithms provide sufficient capabilities to realize the presented navigation system and to determine precisely a position of the pipeline defects.

VI. REFERENCES

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