Evaluation of Inner Pipe Wall Deviation

Michal Kelemen*, Ľubica Miková, Ivan Virgala, Tomáš Lipták

Department of Mechatronics, Technical University of Kosice, Faculty of Mechanical Engineering, Kosice, Slovak Republic

*Corresponding author: michal.kelemen@tuke.sk

Abstract Paper deals with inner pipe locomotion. In-pipe machines locomote inside pipe to make inspection, pipe repairmen or cable drawing into old pipes. Inner pipe wall deviations have significant influence to locomotion inside pipe. This is reason way it is necessary to identify of inner pipe wall deviations.

Keywords: pipe, locomotion, deviation, tolerances


1. Introduction

Currently pipe systems are mainly used for gas and liquids transmissions. There are pipe systems for distribution of water, gas, oil, waste water. Also industrial application as chemical plant, food processing, metallurgy, energy systems, power plants etc. includes any form of pipe systems.

Many pipe systems need periodical inspection (steam generators in nuclear power plants, boilers and heat exchanger and pipe systems in chemical plants). There is a place for in-pipe robots, which are able to locomote inside pipe and make inspection. In-pipe inspection is considered as objective method for crack detection and in some cases it is only one possible way of pipe inspection. There are very known facts about accident in nuclear power plant, which has very bad impact to people and environment. These damages caused with pipe crack are higher than value of the pipe system. These facts were the initial impulse for in-pipe inspection developing. Some pipe systems are placed in environment, which is dangerous for people, so this is area right for in-pipe robots. In-pipe inspection is always cheaper than eliminating of accident results. It is very difficult to develop universal inspection in-pipe robots. In the most cases is possible to determine concrete conditions, in which the robot will locomote. Following this condition, the way of locomotion and sensing system are selected. Situation is more complicated if inner pipe diameter decreased.

Sometimes the old pipe can be used for cable drawing without excavation works, which are too much expensive and it is again place for utilise of in-pipe robots.

Many times we see excavation of our streets, because of any damage on gas pipe etc. This is a place for applying of repair in-pipe robots.

In-pipe robot can be arranged as modular system with several modules because of better locomotion through the curved pipes. Robot consists of energy module, connecting module, end module, control module and drive module.

Composition of machine can be arranged in accordance with application. Minimum configuration contains driving module and end module (Figure 1). Nevertheless, it is possible to make configuration with two drive modules and three energy modules analogous to train. Every module is connected to other via using the spring joint, which enables very good manoeuvring to cross also elbow and T – joints (Figure 1).

Figure 1. Wheeled in-pipe inspection robot

Problem, which is necessary to solve, is slipping of wheels on inner pipe wall caused with inner surface pipe wall. Also sediments are frequently on inner pipe wall.

Design of these inspection devices requires the information about the status of inside pipe wall. It means the information about inner diameter, deviation of shape and position, micro geometry of the inner pipe wall.

Inaccuracy of the inner pipe wall is represented with deviations of real inner pipe surface from geometric surface. Geometric surface is nominal surface and it is theoretic surface described with standard dimensions.

Real inner pipe surface comes from production process and from using in any energy devices. The real surface has stochastic character and it is impossible to clearly realise.

Geometric deviation can be divided into these main groups:

a) deviations of the nominal dimension,

b) deviations of the geometric shape,

c) deviations of the relative position,

d) roughness of the surface.
Pipe producers specify only the tolerance of the outer pipe diameter and tolerance of the pipe wall thickness. There is no mention about tolerance of inner pipe dimension. Production tolerance of inner dimension can be obtained with solution of the dimension chains.

The paper describes experiments with new unused pipe specimens and pipe specimens from energy devices used in high pressure and temperature.

2. Nominal Dimension Deviation and Round Deviation of Inner Pipe Wall Surface

Method of pipe cutting has been used for obtaining information about the inner diameter, deviation of dimension and round deviation. Samples have been cutted from pipes at randomly selected place. The length of the specimens are 45 mm. Cutting has been realised via cutting-off lathe. Cutted surfaces have been grinded. There are explored 98 samples cutting for mentioned experiments (Figure 2).

Cutting surface of the pipe samples have been projected in enlarged scale via Profilprojector 600 from ZEISS Jena. Scaling factor of enlarging has been selected (10x, 20x, 50x) in accordance to diameter of measured sample. Result of the projecting is enlarged plan of the sample cross section. This enlarged cross section enables to evaluate dimension, deviation of the dimension and round deviation.

Main advantage of this method is that it is possible to obtain continuous record of the inner wall profile of the pipe sample. Another advantage is the possibility of measure of pipe with small diameter (Figure 3).

Exploration of the state of the art in the area of measurement of geometric characteristic shows that there is no standards and algorithms for exploration of the geometry of inner pipe wall. The problem with measurement is mainly in pipes with small diameter (under the 50 mm).

Method of sample cutting can be selected also another as the water beam, laser beam etc. It is important to cut sample without deformation of its cross section [2].

Recorded pipe profiles have to be used for evaluation of the round deviation. Round deviation has been evaluated as maximal deviation of the real measured profile from the envelope circle (Figure 4).

Values of the maximal round deviation lie between the range from 170 to 2700 μm [2].

Deviations of the nominal dimension have been evaluated from the same recorded pipe profile (Figure 5). These values lie between the range from -500 to +4150μm [2].

Production tolerance of the inner pipe diameter is possible to evaluate from the calculation of the dimensional chance.

![Figure 2. Samples of pipes](image1)

![Figure 4. Evaluated round deviations](image2)

![Figure 3. Polar diagram of the pipe cross section](image3)

![Figure 5. Evaluated deviation of the nominal dimension](image4)
Figure 6. Tolerance region for deviation of the nominal pipe inner diameter

3. Roughness of Inner Pipe Wall

Roughness of the inner surface is described via quantities of the surface roughness defined in standards. Neither of the producers specifies inner pipe surface roughness. Roughness has been identified from measurement realized on the same pipe samples. Measurement has been realized on inner pipe surface in longitudinal direction (Figure 7, Figure 8).

The aim of the measurement has been to obtain:
- middle arithmetic deviation of the explored Ra. It is defined as middle arithmetic value of the absolute deviation of the profile,
- curve of the material ratio (Abbot Firestone curve) which is defined as curve of material ratio of the profile in dependence on position.

Profile of the surface is sensed as profile, which is produced with cutting of the real surface. Real surface is sensed as surface, which separate the body from surroundings.

Measurement has been realized through the contact method with roughness measurement device (Figure 7, Figure 8).

Middle arithmetic deviation of the surface roughness has been in range 0.32 μm to 1.03 μm for unused pipe samples (Figure 9) and in range 0.69 μm to 3.64 μm for used pipe samples (Figure 10).

Several samples of used pipes have inner surface very damaged otherwise with dirt. In these cases, the roughness cannot be measured.

Figure 7. Roughness measurement of inner pipe surface

Figure 8. Detail of roughness measurement

Figure 9. Middle arithmetic deviation of the surface roughness of unused new pipes

Figure 10. Middle arithmetic deviation of the surface roughness of used pipes

4. Conclusion

Inaccuracy of pipes i.e. inner pipe surface is very significant for in-pipe machines, which locomote inside pipes.

It is possible to summarise several points on the base of realised analysis and measurements:
- Width of the production tolerance range for unused pipes is between the interval from 1 to 3.5 mm (for pipes with inner diameter under the 50 mm).
- Deviation of the nominal inner diameter for used pipes has been in range – 500 to 4150 μm.
- Round deviation for inner surface has been in range 170 to 2700 μm.
Middle arithmetic deviation of the surface roughness has been in range 0.32 μm to 1.03 μm for unused pipe samples and in range 0.69 μm to 3.64 μm for used pipe samples.

Knowledge about the inner pipe wall deviation will help to design and develop suitable in-pipe robot for locomotion inside pipe [14-19].

Acknowledgements

The work has been accomplished under the research projects No. VEGA 1/0872/16 financed by the Slovak Ministry of Education and project “Design and realization of pneumatic manipulator” financed by the Faculty of Mechanical Engineering at the Technical University of Kosice. This contribution is also the result of the project implementation: Centre for research of control of technical, environmental and human risks for permanent development of production and products in mechanical engineering (ITMS:26220120060) supported by the Research & Development Operational Programme funded by the ERDF.

References