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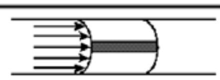
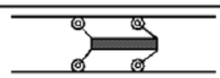
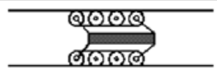
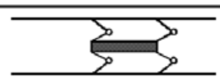
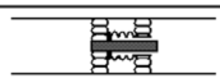
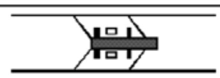
MOBILE MICROMACHINE

In-pipe mobile micromachine, difference friction force, shape memory alloy actuator

This article describes design of in-pipe micromachine, which is able to self motion in the thin pipe (20,3~22,3mm inner diameter). This micromachine for moving utilises of shape memory alloy (SMA) actuator. On the base of analysis in-pipe motion modes, the motion principle in-pipe micromachine based on difference friction force between contact elements of micromachine and inner pipe wall has been chosen It also explains mobile sequence, design of micromachine contact elements and experiment of friction coefficient.

1. INTRODUCTION

In recent times the mobile machines for movement in the thin tubes (about 10 mm) represent developed area of research. They are used mainly for surface defect monitoring in thin tubes.

Motion modes	**1.Pressure of fluid**	
	2. Wheeled	
	3. Crawled	
	4. Legged	
	5. Inchworm	
	6. Vibrations	
	7. Travelling wave	

Tab. 1 The in-pipe locomotion taxonomy

Because of the size limitations of classic wheel and crawling traction principles and results of the energetic fields generating the forces for actuator driving there is a need of different approach to the design and manufacturing than in macro world. In-pipe micromachine is designed to motion in straight pipe in 20,3~22,3mm inner diameter which is used in steam generators in nuclear power stations. After application of suitable surface defects sensor it is possible to realise scanning inner pipe wall. It can useful when cable for introduction of optical or electrical cables is pulling and for other work in pipe.

In-pipe locomotion taxonomy from view of biological analogy:

- artificial locomotion (see tab.1 – pos. 2, 3)
- biological inspired locomotion (see tab.1 – pos.1, 4, 5, 6, 7)

2. PHYSICAL MODEL OF MOTION PRINCIPLE

Fig. 1 shows physical model of micromachine motion principle. If the spring is stretched out, distance L is enlarging then a point B is sliding forward on plane and a point A is locked as a result of larger friction force by backward motion. If the spring is contracting, a point A is sliding forward on plane and a point B is locked. When the length of spring is oscillating, the motion is implicated forward.

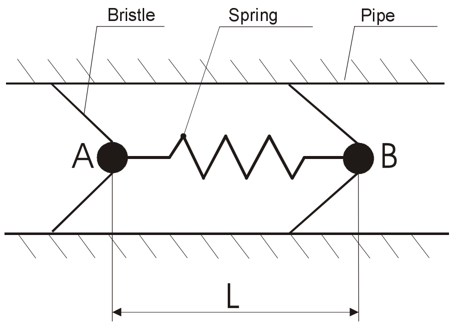


Fig.1 Physical model of motion principle

3. DESIGN OF CONTACT ELEMENTS

Bristles have dominant influence on motion parameters. These contact elements create force feedback between micromachine and inner pipe wall. The aim is to design of elements with maximum difference friction force for forward and backward slip. Up to now used contact elements are bristles or flexible blades in different shape. Their disadvantage is expressive dependence on difference of friction rate on roughness and hardness of pipe wall. Original contact elements have been designed to eliminate this defect (Fig.2). The idea of solution is to use combination of two different materials with expressive difference of friction rate towards pipe wall. These two different materials are metal & rubber.

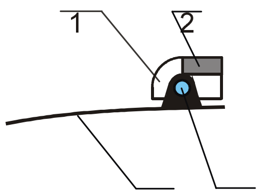


Fig. 2 Design of contact element
1-metal gripper , 2- rubber contact, 3- pin, 4- flat spring

<u>Forward motion:</u>
- the first phase - a contact element is generating on the pipe wall
- the second phase - a contact element is sliding on the pipe wall

<u>Backward motion:</u>
- the first phase - a contact element is generating on the pipe wall
- the second phase - after rubber contact reaches the pipe wall, friction force is increasing expressively and a contact element is locked.

The position of contact element for forward and backward motion is shown at the Fig. 3.

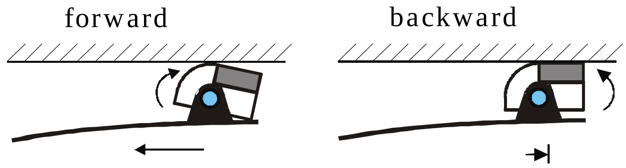


Fig.3 The position of contact element by motion

Mechanical properties of contact elements have been tested on experimental model by declinable tribometer. The results of experiment have confirmed the existence of sufficient difference of friction force for forward and backward motion.

4. IN-PIPE MICROMACHINE DESIGN

In-pipe micromachine design is shown at the fig.4 and its 3D model at the fig. 5.

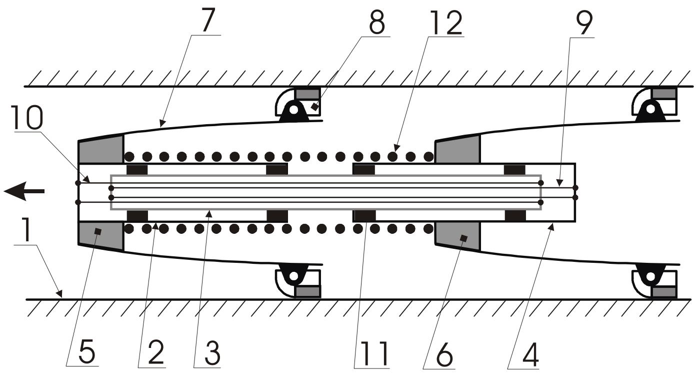


Fig. 4 Global arrangement of in-pipe micromachine
1-pipe, 2-front tube, 3-middle tube, 4-rear tube, 5-front flange, 6-rear flange, 7-flat spring , 8-contact element, 9-rear SMA wires (4x),10- front SMA wires(4x), 11-guide bush, 12-compression spring

The basic part of micromachine is linear actuator, which is consists of front, middle and rear tube. They are connected together by guiding bush. SMA wires (Flexinol 100 HT) are actuating units. Four wires are used parallel to get required load. The connection of SMA wires reduces the length of actuator in 40 % (SMA wires stay unaffected). Which SMA wires are heated by current, they are contracted in 5 % what causes reduction of actuator length in 6mm.

When electric power supply is interrupted, SMA wires are getting colder and they are elonged to initial value (it requires return force). The compression spring creates required reversible force of actuator units and force for front module motion when SMA wires get colder.

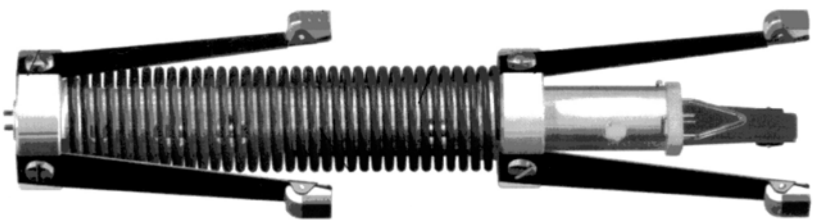


Fig. 5 3D micromachine model

On the front and rear tube of actuator is connected front and rear flange with three flat springs and contact elements. Contact elements are supported on pins.
The micromachine can by used for pipe in larger diameter, while suitable templates under flat springs are embedded.
The maximum drive force is 1 N and the maximum theoretical velocity is 275mm/min.

5. MOBILE SEQUENCE

Micromachine for moving uses inchworm principle.

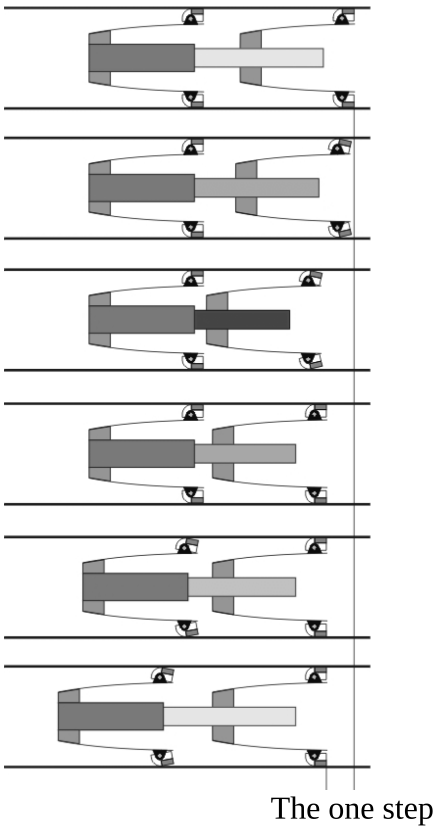


Fig. 6 Micromachine moving algorithm

6. EXPERIMENT OF FRICTION COEFFICIENT

Goal of measurement is to determine friction coefficient of backward and forward motion (see tab. 2). For measurement of friction coefficient f_s has been used principle declinable tribometer (fig. 7). This measuring device consist of an inclined (motor driven) plane. Surface of this plane is one of the examined pair of material. Solid, which is able to move on this plane, has connecting area from second material of examined pair. For friction coefficient is valid following formula:

$$f_s = tg\alpha$$

where α is angle, when solid starts to move.

Friction coefficient depends as well on surface roughness, so for surface of inclined plane is good to use material, which has Centre Line Average value of surface (R_a) equal to Centre Line Average value of inside´s pipe wall surface. Values of R_a and profile bearing length ratio of metal sheets are compared to values of inside´s pipe wall. Practically not every pipe has the same value of R_a, so it is more advantageous to measure friction coefficient on surfaces with different values of R_a.

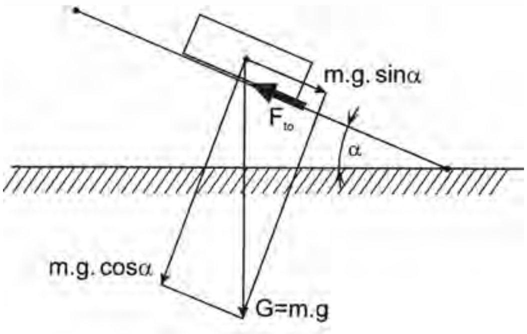


Fig. 7 Principle of declinable tribometer

For purpose of experiment has been realised simplified model of contact elements micromachine (fig. 8).

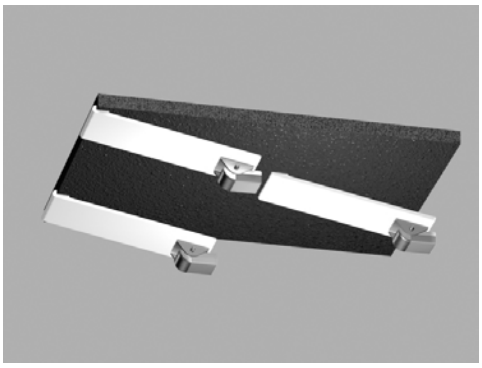


Fig. 8 Design of contact element micromachine

Friction coefficient has been done on three different surfaces:

- metal sheet (11305) in the way of rolling ($R_a = 0{,}93 \pm 0.08 \mu m$)
- metal sheet (12090) against the way of rolling ($R_a = 0{,}57 \pm 0.16 \mu m$)
- glass

Simplified model has been completed with weight, while total loading was 167,2g.

Applied force value has been chosen with regard to assumed loading of contacted elements on real micromachine.

Table. 2

Measured friction coefficient

Material of basis	Sheet steel 11 305		Sheet steel 12 090		Glass	
Friction coefficient	Front f_{s1}	0,191	Front f_{s1}	0,201	ahead f_{s1}	0,130
	back f_{s2}	0,775	back f_{s2}	0,582	back f_{s2}	0,483
ratio f_{s1}/f_{s2}	4,058		2,896		3,715	

Form values of friction coefficient which has been measured is evident that:
- Friction coefficient depends on Centre Line Average value of surface (R_a) of inclinated plane´s surface. However ratio f_{s1}/f_{s2} is with every single surface remarkable.

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ON-LINE SUBTRACTION METHOD FOR MAINS INTERFERENCE REMOVING FROM ECG SIGNALS WITH SIGNAL PROCESSOR

Keywords: ECG signal, on-line, notch filter, subtraction method, DSP

In this article we described the subtraction method for removing mains interference from ECG signals and realized its algorithm in real time by digital signal processor. Tree filtering procedures included in our algorithm are organized as separate modules, which permit us to apply various types of filters without changing the main structure of the algorithm. This organization is very useful and gives us a possibility to analysis and optimization of the subtraction method.

1. INTRODUCTION

There are many methods for suppressing mains interference from electrocardiosignals (ECS). Analog and conventional digital filters are not effective, because they affect some of the useful high frequency signal components adjacent to the mains frequency. This is due to the fact that frequency spectrum of most biomedical signals superimposed with those of mains interference