Automatic Surface Damage Exploring and Repairing System by Precise Micro Robots

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1. INTRODUCTION

In recent years, many types of micro robots and locomotion mechanisms have been developed as high precision positioning tools and opened new application in the filed of not only precision engineering but biochemical one. Particularly the piezo driven mechanisms can allow the excellent positioning resolution of nanometer level within an infinite workspace although the feedback properties with external sensors are required to improve the coordinate accuracy over the working area[1]. Also the micro robot has the potential performance for the application in the special environment such in-pipe and in-chamber where it is difficult for the conventional mechanism to extend its arm. Surface investigation of the product and the facility with complex curved surface, in which small mechanical defect should cause the serious problem, needs much of efforts to do.

Our group have developed many small robots with micro tools and sensors on the precise locomotion platform which is composed of piezo elements and electromagnets. Basic structure and performance were reported in the previous papers[2].

In this report, the newly developed micro robots which can explore on the target surface in order to find out the mechanical damages such as crack and defect, and propagate the acoustic signal in order to indicate the damage location by the passive resonator are described. And another one which has dual microphones to detect the acoustic signal and maneuver itself automatically to repair the crack automatically is also explained.

As illustrated in Fig.1, these small robots can collaborate each other on the target to perform this unique task. This system can allow the low cost precise inspection and automatic repairing over night without any expensive facilities.

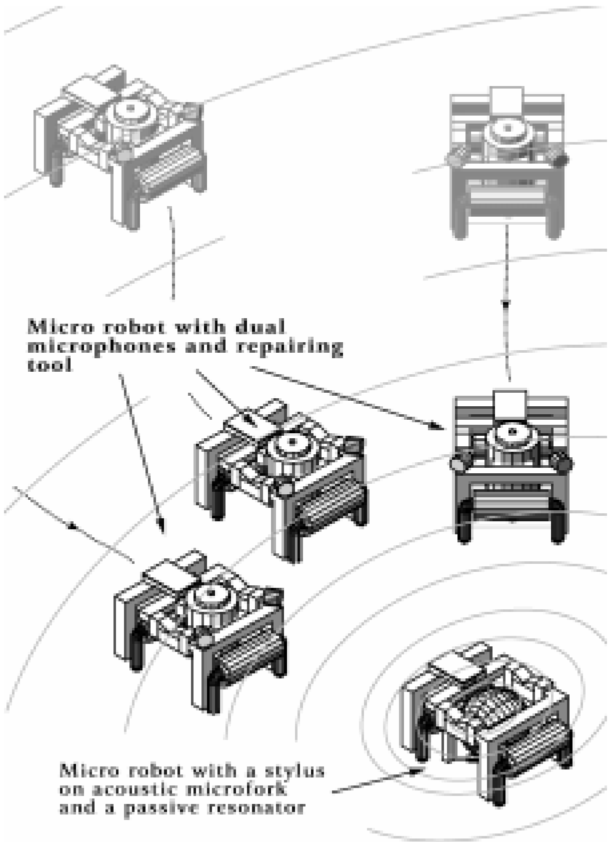


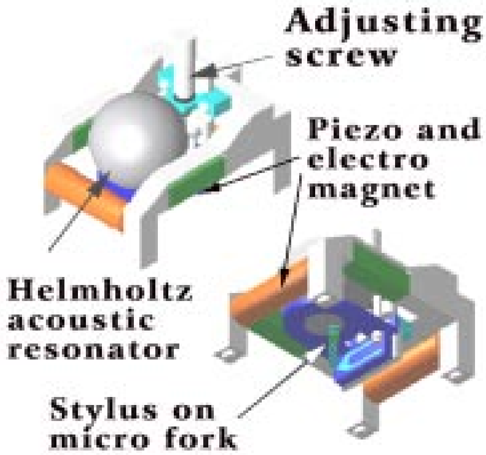
Fig.1 Conceptial schematic of micro robots for automatic surface damge inspection and reparation

2. MICRO ROBOTS FOR SURFACE DAMAGE INSPECTION AND REPARATION

2.1 Micro robot with stylus on U type micro fork and acoustic resonator

The micro robot which can explore on the target sample and detect the mechanical crack, and then propagate its acoustic signal by the

(a) Photograph of the developed small robot



(b) Isometric view of the small robot

Fig.2 Micro robot with a micro fork with stylus and a passive acoustic resonator

passive resonator is shown in Fig.2. This small robot, 40mm in height, 40mm in width and 60mm in length, has piezo element and electromagnet to move precisely based on an inch-worm principle. Furthermore it is incorporated with a stylus set at the end of the micro sound fork excited by the piezo film and a passive Helmholtz resonator.

When the stylus traverses over the small crack, it is free of contact so that it can start to vibrate at its resonance. However the vibration is suppressed so as to give no signal when keeping the contact with the plane surface, as shown in Fig.3. The amplitude of stylus vibration of several ten micron should be determined according to the depth of crack to be checked. For instance, the acoustic signal can be oscillated when the micro fork stylus with the amplitude of 20 micron goes over the defect of deeper than 20 micron.

A simple passive acoustic resonator is equipped with the robot in order to propagate this insignificant trigger signal to other small robots with repairing tools without any supplemental electronics and any wires. This idea partially comes from the insect world such a mosquito wing and a cicada's resonator. The volume of cavity and the diameter of orifice should be designed carefully to match to the micro fork resonance frequency.

In the experiment as mentioned below, the commercially available U type micro fork with the dimension of 1.5mm in width, 8mm in length, and 0.5mm in thickness is used for a pickup device, which has the resonance frequency of 1000Hz excited by piezo film. And a thin stylus of tungsten with 0.1mm diameter is attached at the end of this micro fork as an active feeler. To amplify this small vibration for propagation, a passive Helmholtz spherical resonator with the diameter of 25mm and 3.0mm orifice are designed and implemented close to the micro fork.

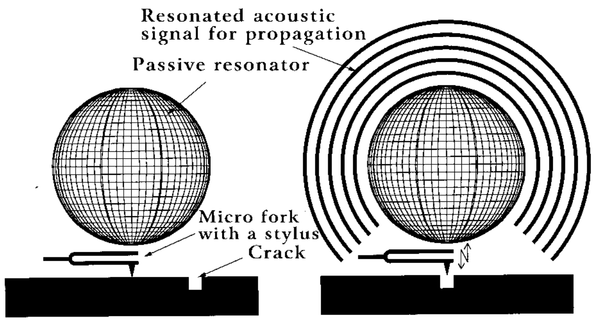
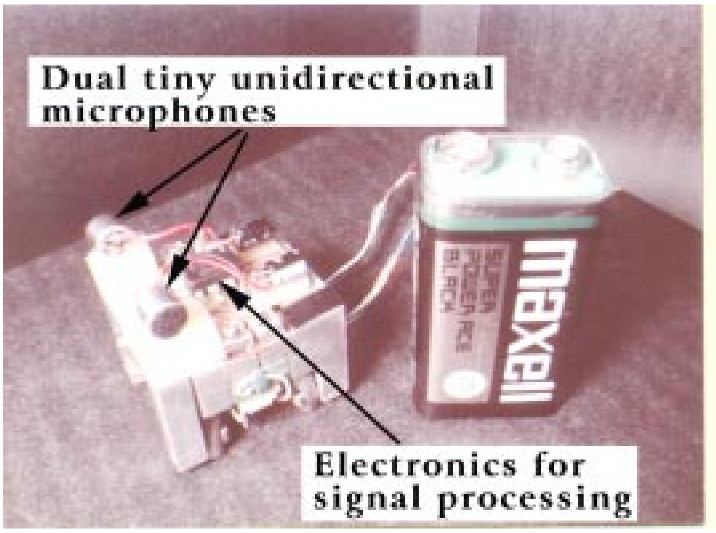


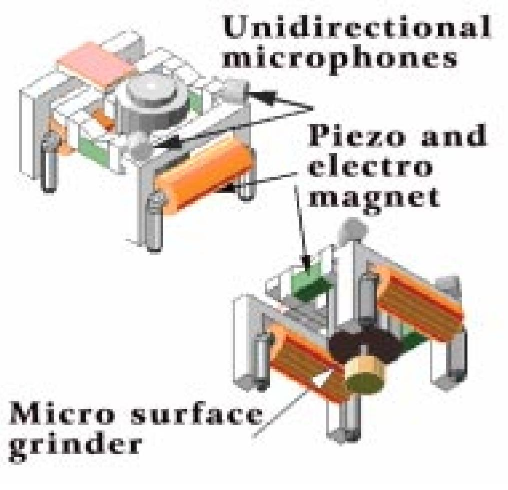
Fig.3 Principle of crack detection; a stylus set at the end of the micro fork excited by the piezo to scan the surface and its acoustic signal can be resonated by the passive resonator for wide propagation

2.2 Micro robot with microphone and repairing tool

After the location of the defect is identified by the small robot with a stylus sensor, other small robots with a repairing tool have to move toward the destination automatically. To



(a) Photograph of the small robot with dual tiny microphones to detect the signal source



(b) Conceptual view of the robot with dual microphones and simple micro grinder to finish the surface on going development

Fig.4 Micro robot with dual unidirectional microphones to detect the signal source from the small robot with a vibrating feeler

prevent the system being complicated, each small robot is required to maneuver itself by the reflective manner based on the simple control sequence. So a pair of tiny unidirectional microphones with a primary electronics are embedded on the robot to detect the direction of signal source which is generated by the vibrating stylus as shown in Fig.4.

The detected acoustic signal from two microphones can be compared to the threshold and turn on the piezo actuation. And the differential amount from two sensors also can be used for switching either of two piezo elements to control the heading of the robot. This simple sensor and the primary signal processing device allow the small robot to move automatically toward to the source of acoustic signal which indicates the surface damaged point. Since there should be many kinds of damage and crack on the surface, we have to investigate these characteristics. Currently we are designing two small robots on going development , one of which has a micro electro discharge tip to mold the crack and the other has the micro grinder to finish the surface.

3. EXPERIMENTS

As a primary experiment, the sample with the several grooves of 30 micron to 120 micron depth is used to check the basic performance. The amplitude of the vibrating stylus as a threshold value can be controlled easily by the

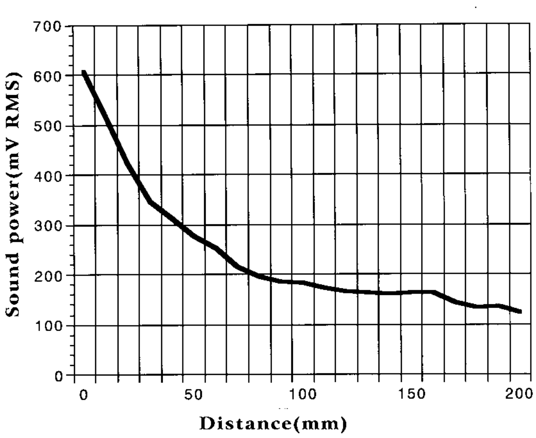


Fig.5 The relation between the distance from the resonator and the acoustic power which can shows the workable ranging by acoustic propagation

input voltage applied to the piezo film on the micro fork.

It was confirmed that the resolution is approximately 10 micron within the range from 30 to 120 micron. However the amplitude of vibration smaller than 50 micron causes the decrease of acoustic propagation range from the resonator, and consequently other robots with microphones should lose the signal destination. In the practical application on the desktop, the acoustic signal of the crack deeper than 50micron can be enough to be detected

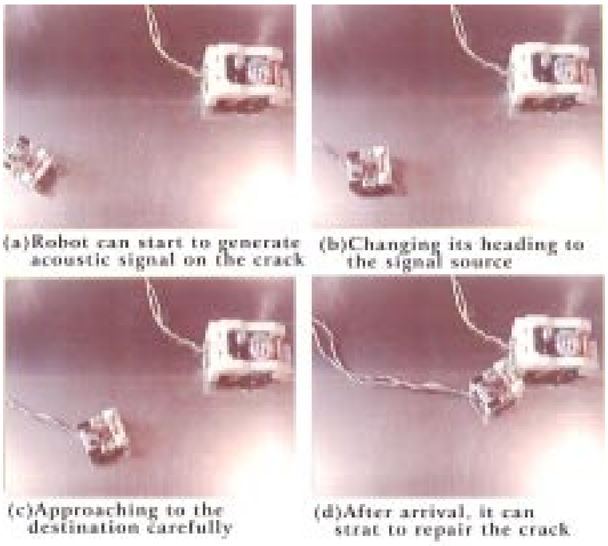


Fig.6 Sequencial photogpaphs show the basic performance for the small robot with microphones to move toward to the singnal source generated by the tiny micro fork on the sample crack

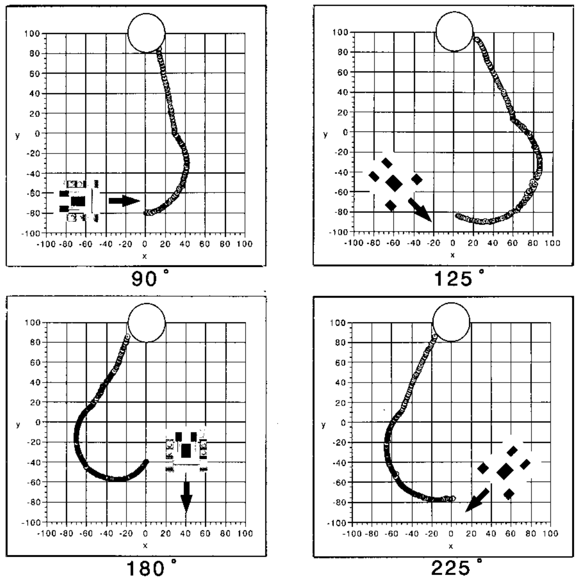


Fig.7 Tracking accuracy for several different initial headings of the robot

and the defect location can be informed to other small robot for automatic navigation.

In Fig.5, the relation between the distance from the resonator and the acoustic power which is able to be detected by the microphones is shown. It is understood that the acoustic signal of the 50 micron depth can be extended within approximately 200mm in any direction although it diminishes with the respect the distance.

Fig.6 shows the typical experimental results that the small robot can explore on the target surface for inspection and detect the mechanical crack such as groove and scratch. Then the contact-free micro fork with a stylus begins to vibrate at its resonance and this microscopic vibration can be amplified by the passive resonator to activate and navigate the other micro robot. The robot with microphones can successfully detect the acoustics trigger signal and move toward the signal source generated by the small robot with a stylus

Several approaching paths to the signal source from the different initial positions of the small robot were investigated to check the tracking accuracy as shown in Fig.7. This shows that the small robot with tiny microphones can be controlled to move automatically toward to the location of mechanical damage to be repaired from any positions in the working area.

4. CONCLUSIONS AND FUTURE WORKS

In this report, the unique micro robots developed for automatic surface damage inspecting and repairing system was described. One of them has U shape piezo excited micro fork with vibrating stylus and acoustic resonator to scan the surface and provide the acoustic signal which is containing the surface roughness. The measuring range of the surface defect depth is approximately from 30 micron to 120 micron with the resolution 10 micro as a threshold for inspection. The other one has dual microphones which can detect the signal source direction and can control the heading to move toward the signal source automatically. The workable range of this small robot is within 250mm to detect the acoustic signal. Currently the surface repairing tool of micro EDM and surface grinding tool are also implemented to accomplish the specified tasks.

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