# AN ELECTRICAL RESISTANCE TOMOGRAPHY BASED MATRIX PROBE FOR OIL-WATER TWO-PHASE FLOW

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*Abstract* Electrical Resistance Tomography (ERT) is a powerful method for mapping the phase distribution in multi-phase flow. However, this method requires a process of image reconstruction which is not sufficient to meet the demand of online real-time measurement. In this paper we developed a new type of matrix probe sensor for cut-plane real-time tomography measurement. The sensor points array as a matrix in a transparent pipe, which can directly measure the conductivity of the flow medium at each point. The device was tested in a horizontal two-phase flow system, and a high speed camera was used to visualize the flow pattern for the comparison. It was found that, with the new device, the measured results of both flow pattern and water content agree quite well with that of high speed camera and supply data.

## INTRODUCTION

Oil-Water two-phase flow exists widely in modern industrial processes such as petroleum exploration, chemical industry and other domains. It is of great importance to study the behaviours of phase distribution, or flow pattern, as it plays one of the most important roles that dominate the flow characteristics. Therefore the measurement of phase information, especially visualized distribution, is an attractive subject for the study of multiphase flow. Electrical Resistance Tomography (ERT) was invented in 1990s, which was soon introduced from medical research to engineering applications [1]. It has been proved to be a powerful method for mapping the distribution of each phase in pipe flow [2]. Since this method is based on some image reconstruct algorithm, it is not accurate and fast enough to meet the demand of online real-time measurement. In this paper, we designed a new type of matrix probe sensor which is capable of quick measurement. In the new device a metal ring mounted on the inner wall of the pipe acts as the positive pole, which excites the continuous phase of water. The sensor points, array like a matrix, directly meter the electric potential of each location on a cut-through plane in the pipe (refer to the equipment fabrication below). The principle of the method is based on the different conductivity between the two phases, therefore it is probable to measure the air/water as well as oil/water two-phase flow. It doesn't need any algorithm to reconstruct the image, so the accuracy problem is out of consideration compared to the traditional ERT method. Another advantage is, since the measured information is the phase distribution image of the cross section, it is also possible to calculate the dispersion coefficient of each phase in the section.

## EQUIPMENT FABRICATION

The main part of the sensor is the distributed probes. In order to insert large amount of probes into the pipe with least interference, a novel technique, -- namely flat cable craft, was developed after a period of challenges. In consideration of the wetting property of oil and water we choose polyimide film as the carrier of the probes. Both probes and the carrier polyimide film is designed as thin as possible, and what was approached at present time is with a thickness of 0.15mm and a width of about 2mm. Metal film sticks on each side of the polyimide carrier, covered with another layer of insulation film, is almost the same as a flat cable's craft in a usual mobile phone. Every cable has eight probe points retained which was uncovered as shown in Fig.1. We assembled eight cables into a non-conductor, a ring made of epoxy material (Fig.2) with the same inner diameter as the pipe. Finally a copper ring is attached onto the back of the sensor system which serves as the positive pole. During the tests, those probe points that soaked in the water phase show a high voltage, while the others soaked in the oil phase show a low voltage (Fig.3), and this offers direct information of phase distribution. Fig.4 shows the measure circuit, powered with a chipset STC12C5410AD MCU.

Fig.1 Flat cable

Fig.2 Matrix assemble

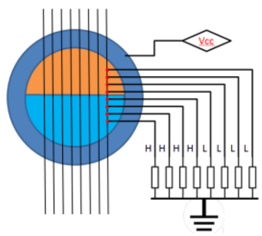


Fig.3 Principle

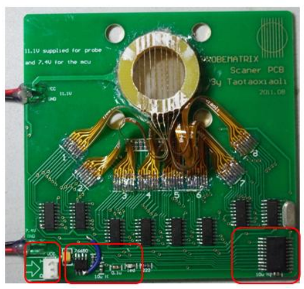

Fig.4 PCB circuit

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## EXPERIMENT SETUP

The experimental system includes tanks, pump, oil-water separator, turbine flowmeter and other standard equipment (Fig.5). The sensor was fixed onto a transparent pipe with an inner diameter of 20mm with flange connection (Fig.6). The oil pump gives a steady flow rate from 0.3$m^3$/day up to 4 $m^3$/day while the water pump from 2.7 $m^3$/day up to 54 $m^3$/day. From the reading of the flowmeter, water content and flow velocity in pipe can be calculated. Different flow patterns can be obtained depending on various oil-water contents and flow rate. The oil phase used in this experiment is 0# diesel oil. The flow configuration was visualized with a high speed camera, SANYO HD1010, whose highest resolution is 1280*720 pixels. The PCB circuit scans the 8*8 probes within about 0.3ms, which is quick enough to apply for static hypothesis. MCU on the circuit packs the data and sends it to the PC via a USB-SERAIL PORT. A GUI(Graphical User Interface), developed under the environment of VB(Visual Basic), receives the data and unpacked it into the images, which forms online real-time movie.

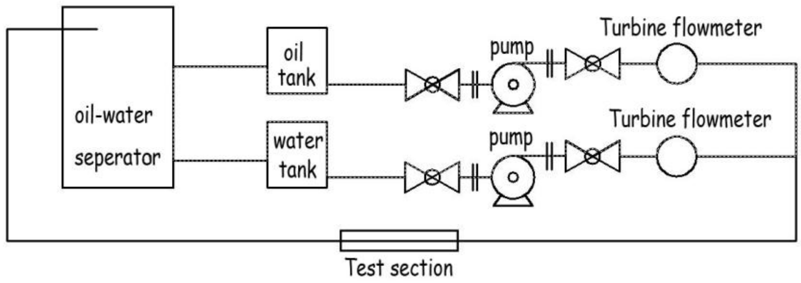



Fig.5 The experimental system

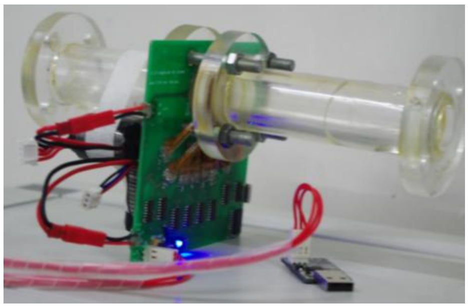


Fig.6 The sensor fabrication

## RESULTS AND DISCUSSION

### Image Reconstruction and display

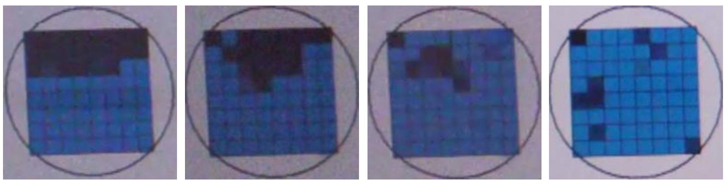
Fig.7 shows the image reconstruction results under different flow patterns, in which dark blue points represent oil phase and the others are water. From the pictures we can easily tell the pattern difference. The resolution of the image depends on the amount of probes (8*8=64 points in this test). But more probes mean more interference, so it must be balanced.

### Velocity Measurement Discussion

Since the sensor can measure the distribution of the oil phase, it is possible to combine two set of sensor to form a dual-plane sensor, so that the velocity of the disperse phase can be obtained based on cross correlation methods [3].

### Water Content and Discussion

In the present experiments, flowmeters were used to measure the rate of oil and water, from which the water content can be calculated. On the hand, the phase distribution images obtained with the new device can also offer the information of water content. Fig. 8 shows the comparison between the two methods, which demonstrates quite acceptable agreement.



Steady stratified flow | O/W stratified flow | O/W Dispersed flow | O/W Completely dispersed flow

Fig.7 Image reconstruction result under different patterns

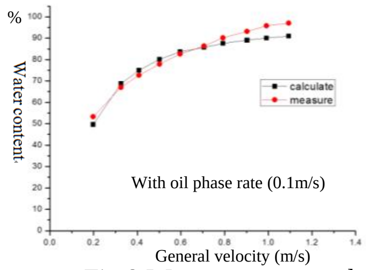



Fig.8 Water content result

## CONCLUDING REMARKS

This paper presented a new type of probe sensor for two-phase flow measurement. Due to its attractive capability of online real-time observation and measurement, more works are planned to be carried out in the near future, such as flow pattern recognition, pattern transition, etc. Another promising work might be the development of Dual-plane sensor, after which it may become a more useful method for both basic research and application purpose.

### References

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