알루미늄 파이프의 홈탐지 센서개발

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Development of Groove Detection Sensor in an Aluminum Pipe

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Introduction

Concealed defect or crack in metallic objects may cause serious consequences in their applications, but is difficult to locate with simple examination devices. In chemical processes, the defected metallic equipments and pipes often result in a large scale fire or explosion leading to operator casualties. Most of maintenance in the processes utilizes radioactive material or x-ray detection equipments. However, the instruments are expensive, and handling the hazardous material causes a variety of problems. In spite of the importance of defect detection in the industry, lack of proper detection technique incurs limited examination of the equipments. Recent development of thermographic defect detection systems is expected to solve the problem. For the instances of practical applications, the system has been utilized in the inspection of composite materials [1] and thermal barrier coating [2]. As theoretical studies, the effect of defect size was investigated through numerical computation [3]. However an infrared (IR) camera utilized in the thermographic defect detection is expensive, and its limited imaging resolution makes the detection of small size defects difficult. A low-cost temperature measurement sensor, IR thermometer, is useful device for the thermographic detection system in lieu of the IR camera. Though its resolution is limited, cost benefit and ready availability are merits of the sensor. The IR thermometers were employed to locate a concealed groove as small as 1 mm wide in a metal plate and proved to be effective [4].

In this study, the IR thermometers are utilized to detect a conceal groove in an aluminum pipe. For dense arrangement of the sensors and measurement, optical fiber is attached to the sensor window. The results of temperature measurement around the concealed groove are compared with the computed temperature distribution using a heat conduction equation.

Experiment

1. Preparation of sensor module

The infrared sensor (Heimann Sensor GmbH, Germany, Model 3129) used in this experiment has a circular window of 2.5 mm in diameter detecting temperature. Five sensors are installed at the left end of the sensor module. The circuit has a variable resistor for the adjustment of base signal output. The sensor has an internal thermistor for temperature compensation. Whereas the sensor case is 8.2 mm in diameter, the temperature detection window is only 2.5 mm leaving too much space between actual measurement positions. In order to reduce the distance, an optical fiber (Mitsubishi Rayon, Japan, SK-10) lead is attached. The 7 wires of the 1 mm fiber make a 3 mm circular window for each sensor leaving 1 mm space between the sensing windows. The 5 detection windows are placed in a vertical row, and the top and bottom of the windows two sets of rolls are installed. During measurements the rolls contact on the surface of the pipe maintaining the distance between the pipe and sensor window.

2. Experimental setup

The sample pipe described in the previous section is placed in the middle of experimental setup shown in Figure 2. In order to obtain a uniform temperature distribution in the pipe an aluminum plate of 1 cm thick holding three electric rod heaters is placed on top of the pipe. The heater is 6 mm in diameter and 5cm long of which heat generation is adjusted by controlling supply voltage with a slidacs. In addition, a shallow container of cooling water is placed at the bottom of the pipe. The cooling water of 15℃ from a water circulation bath (Daeil Engineering, Korea, Model DTC-312) is supplied to the container and recycled. The whole system of the sample pipe, heater and cooler is placed on a turn table. The reference temperatures at the top and bottom ends of the plate are measured with a thin wire thermocouple and a temperature indicator. The IR sensors are calibrated with the thermocouple temperature measurement on other sample pipe heated using an electric rod heater.

While the sensor module is stationary, the sample pipe rotates manually. The rotating angle is monitored with a wheeled potentiometer as described in Figure 2. The amplified voltage signal from the sensor module and the signal produced from the rotation detection circuit are fed to a PC through an A/D converter.

3. Experimental procedure

The experiment begins with supplying cooling water, and the heater is activated. In order to obtain a uniform temperature distribution on the sample plate in steady state, the heat supply and cooling are maintained with constant heat supply and cooling for an hour. During the period the temperature distribution on the plate is examined with a portable IR thermometer (Raytek, U. S. A., Model Raynger IP-K) for reference. When the distribution is stabilized, the turn table holding the sample pipe rotates at the speed of 30 degrees per minute and the data of temperature and sample rotation are fed to the PC. The data are stored during the measurement and retrieved for processing after the experiment.

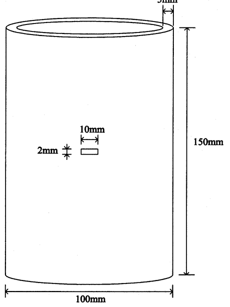

Figure 1. Dimension of an aluminum pipe with a groove.

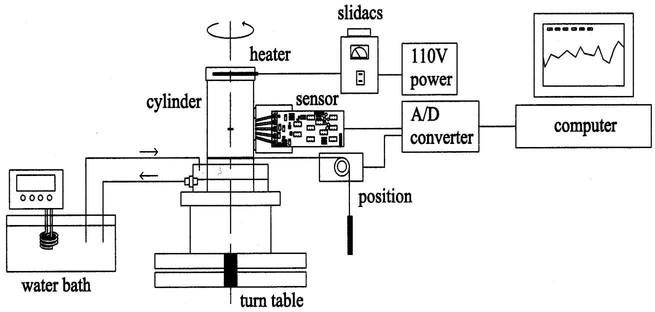

Figure 2. A schematic diagram of experimental setup.

Results and discussion

For the performance evaluation of the proposed detection device, two different settings of temperature distribution in the sample pipe were applied and the surface temperature was measured while it rotated. Figure 3 shows the results of temperature measurement of the sample pipe having top end temperature of 95℃ and bottom end temperature of 40℃. The numbers on the curves are sensor position counted from the top. Because the sensor 3 passes the concealed groove, it shows temperature decrease in the middle of the curve while other curves do not. This outcome clearly indicates that there is a temperature variation at the position of sensor 3 implying the existence of defect.

The experimental measurements are compared with the computational outcome of temperature distribution. The distribution is horizontally uniform except the center where the groove locates. Because no conduction occurs at the place, higher temperature gradient than other locations is observed and a large temperature drop across the groove is shown. The measured temperature at the position also indicates the temperature decrease like the computational outcome. This comparison of measured and computed temperatures was conducted with a rectangular plate, and a similar outcome was yielded [4]. For further performance evaluation, the experimental measurement was conducted with a different temperature profile in the sample pipe. Figure 4 demonstrates the measurement results. The top end temperature of the plate is 110℃ and the bottom end is 50℃. Again, the sensor 3 shows the same temperature variation at the middle of the pipe as seen in Figure 3 whereas rest of the sensors indicate no significant temperature fluctuation.

A similar application and analysis of IR thermometer defect detection device has been conducted with a metal plate [4]. The device is modified by attaching an optical fiber lead at the front of the IR thermometer. Placing the leads in a close row reduces the distance between sensors resulting denser scanning than the previous study. It eliminates the skipping possibility of detection from passing a defect between the sensor windows. One other improvement is maintaining a constant distance between the surface of measuring object and the tip of the optical fiber lead to yield stable temperature measurement. Comparing the outcome of temperature measurement with the previous one demonstrates the improvement.

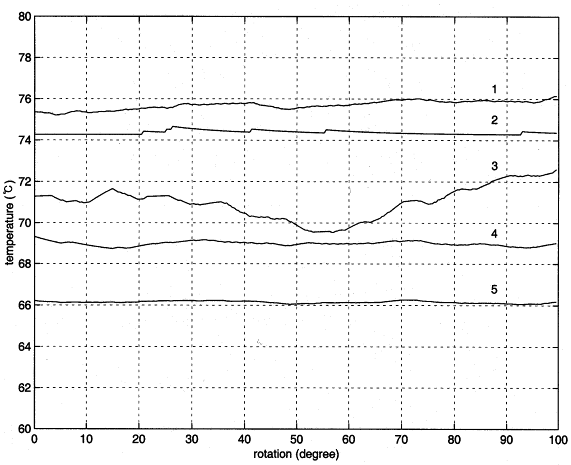

Figure 3. **Variations of measured temperatures in a low temperature pipe.**

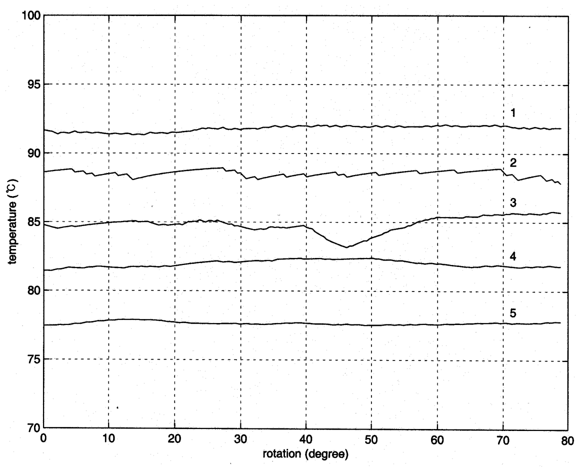

Figure 4. **Variations of measured temperatures in a high temperature pipe.**

Because most of vessels and piping systems in chemical processes are cylinder shape, the proposed device is better to be utilized than the sensor module of the previous study.

In practical applications the temperature of a metallic object is often high enough, and therefore no external heating is necessary like this experiment. This gives convenience to utilize the proposed sensor system. Current techniques of nondestructive defect detection require total shutdown of a process to inspect vessels or reactors, which limits the application of the techniques.

Conclusion

A thermographic device for the detection of a groove in metal plate is modified to use in cylindrical objects. For the easy adjustment of sensor-object distance, an optical fiber lead is attached to the sensor window and rolls are installed on the sensor module maintaining the distance constant.

The temperature measurement results indicate that the modified device yields not only the location of the simulated defect but more stable measurement than the previous thermographic sensor. It is also shown that the measured temperature distribution is comparable to the calculated distribution. Because the proposed device is developed to detect defects in a cylinder, its wide application in chemical processes in which most of vessels and piping systems are cylindrical shape is expected.

References

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