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# Development of Heat Control Valve Using SMA and Remote Controller for House Heating System

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# 형상기억합금을 이용한 난방용 온도조절 밸브 및 원격 제어장치 개발

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**ABSTRACT**

For the purpose of reducing the energy consumption in the house heating, the various devices have been developed. One of these is to control the flow in the heat pipe and the flow control valve using shape memory alloy(SMA) spring is proposed in our study. The proposed house heating system is to save the gas consumption and the remote control system is designed for the convenience of using the proposed valve. The developed valve consists of SMA spring, disk, return spring, and regulation handle. The regulation handle is for supplying the additional hot water and is controlled by remote-control-motor. In order to design the remote control system, the Zigbee wireless communication protocol is used. The performance of the proposed valve structure is shown through the experimental result.

**Key Words :** Energy Saving, SMA Valve, Motor Control, Heating System

## 1. Introduction

The issue of the energy saving has been discussed for years with environmental problem, since the 1973 oil crisis brought energy issues to the forefront. The energy reliant on foreign in the many countries comes up to high percentage and the significant portion is occupied house heating in terms of energy consumption. In order to reduce energy consumption in the house part, the energy saving heating systems required in the heating system. The specific example is to install the thermostatic valve in the boiler system. These thermostatic valves have been widely developed with different types and materials and it has been used for conservation of heating energy in the residential buildings. Generally these valves are to control the flow in accordance with temperature of heating water using a heat detecting sensor or shape memory alloy(SMA)[1],[2]. However, the analyzed data of automatic heating system and the related

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sensors are not enough surveyed and analyzed[3]. Therefore, in our study, the heating system of house using SMA valve was proposed and analyzed the performance of the energy saving. Also the remote control system designed and manufactured to increase the comfortable user interface. The rest of this paper is organized as follows. In section 2 the structure of house heating system, the heating control valve using SMA and the remote control part of SMA valve are presented. In section 3 the result of performance of heating control valve using SMA in terms of energy saving is presented. Finally, concluding remarks are presented in section 4.

## 2. Heating system for house

The types of heating of house are divided into the floor and radiator heat type. In general, the western type of house heating is used by the conventional heat from radiator and some of Asian country included Korea use the floor heating.

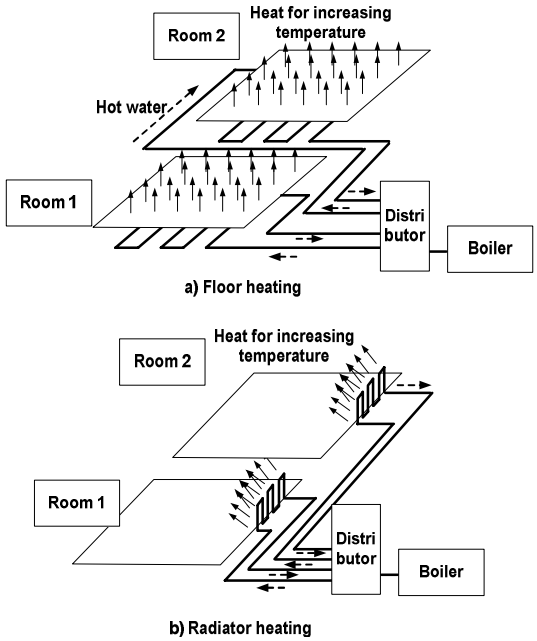


**Fig. 1 Heating type for the house**

The floor heating mechanism is that the heating sources such as boiled water or fire heats the floor first and the heated floor increases the temperature of the house. The compared figures between floor and radiator heating showed in Fig. 1. Generally the house has at least two more rooms and they are also connected with connecting pipes to transfer the boiled water or steam for heating rooms. In order to heat a whole house the individual rooms are heated in order that makes the temperature of each room be a different each other. It can be a major energy loss of house heating system. The method to reduce the energy loss of heating is to attach the valve to control the heated flow through the distributor in accordance with the temperature of each room. In this study, the heat control valve using SMA is proposed. As used the proposed valve, the excessive heat water can be cut and the deviation of temperature of each room is also reduced compared with the case without the proposed valve.

### 2.1 SMA valve for heating

The For the purpose of design thermostatic valve, the following structure proposed in this study. The proposed valve mainly consists of bias spring, disk, cam and SMA spring which is Ti-Ni type. Fig. 2 shows the structure of the proposed valve.

Since the SMA spring can operate only at the set temperature, the regulation handle to open the disk additionally is attached. The regulation handle can control the additional flow regardless SMA motion and it can use to set the comfortable temperature depended on men's feel.

In order to analyze the proposed valve structure, the relations between the elastic coefficients of the bias and SMA spring and constraints of limited length of springs analyzed. Each elastic coefficients of SMA and bias springs are assumed as $k_1$ and $k_2$ and the lengths of them under free load are $l_1$ and $l_2$, respectively as shown in Fig.3. In here, the elastic coefficient of SMA spring is a function of

temperature.

The force of the used SMA spring according to temperature changing represents in Fig. 4. The proposed flow control valve has regulator that is for turning cam and it can provide an additional hot water because the SMA material can move comfortable temperature is different from people. The turning of regulator makes the valve open regardless SMA motion and the related function between degree of the turn of regulation handle and opened disk is as follows:

$$l = l(\theta)$$
$$l^2 - 2cl\cos\theta + (c^2 - r^2) = 0 \qquad (1)$$

In this study, the setting temperature of SMA spring is 40℃ and Fig. 6 shows the flow rate according to temperature variation.

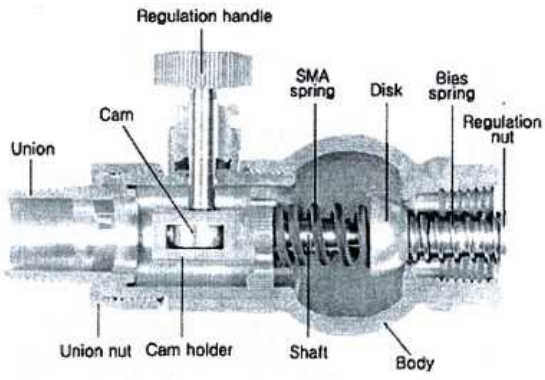


**Fig. 2 Structure of the proposed valve**

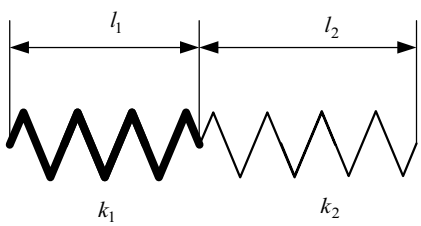


**Fig. 3 Connection of SMA and bias spring**

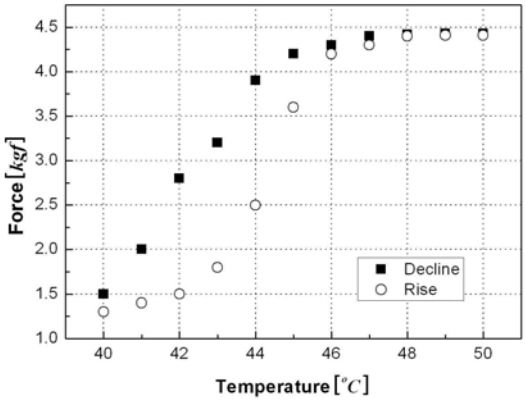


**Fig. 4 Force in accordance with temperature**

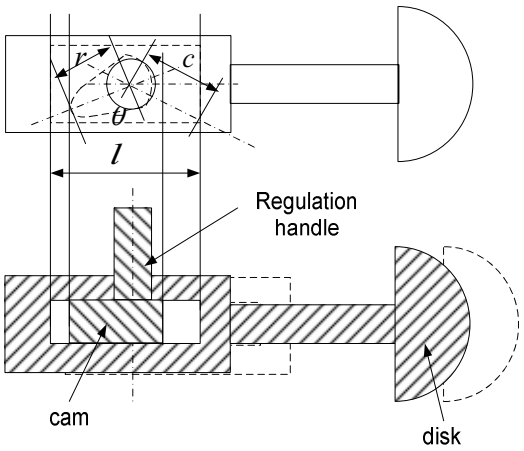


**Fig. 5 Relation between regulator and opened gap**

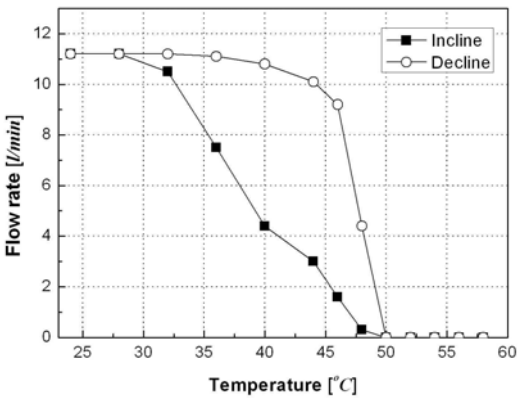


**Fig. 6 Flow rate in accordance with temperature**

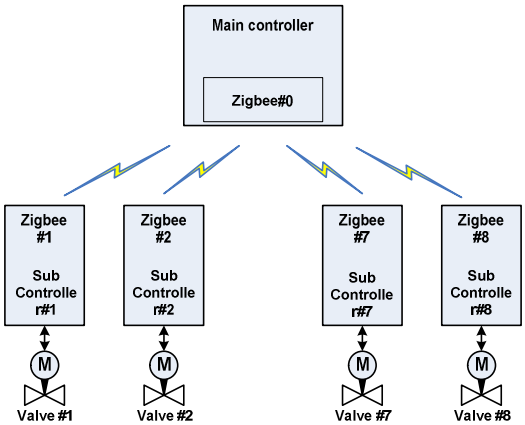


**Fig. 7 Schematic diagram for controlling the SMA valve with motor control**

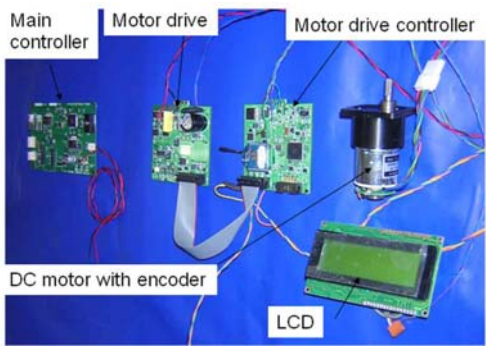


**Fig. 8 Manufactured the motor control and communication parts.**

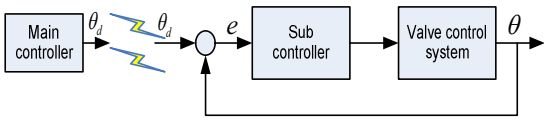


**Fig. 9 Block diagram of motor control**

## 2.2 SMA valve controlled by motor

In our study, the motor is installed with SMA valves to control the regulation handles which are operated by the remote control system. In order to design a motor control part out of whole heating system, motor drive and main control parts are considered. Main control part is designed to supply the reference signal to the motor controller through Zigbee data communication protocol. Because Zigbee protocol can apply to 1:N communication, the main controller can supply the several difference reference signal to each valves through assigning the specific ID. In this system 5 IDs, that is for 5 SMA valve control, are assigned. The DC motor is selected based on the maximum torque of the valve which is measured by torque meter. Also the 1:300 ratio gearbox used to supply the required torque with small size motor. The incremental encoder used to construct the feedback system which controls the flow of SMA valve. The simple schematic diagram of our system represents in Fig. 7 and each part is shown in Fig 8. Each motor is controlled by PID controller and block diagram of motor control system represents in Fig. 9. Based on the designed motor control system, the performance of the controller is tested by sinusoidal signal. Since the heating system is not required fast response, 0.5Hz reference signal is used to test. Fig. 10 shows the reference and output signal and its error signal is shown in Fig. 11. As shown in experimental result, the performance of the command following has under 9% error signal. In this system, the motor controls the amount of switching of valve and under 9% of error signal doesn't affect to the temperature variation in the room.

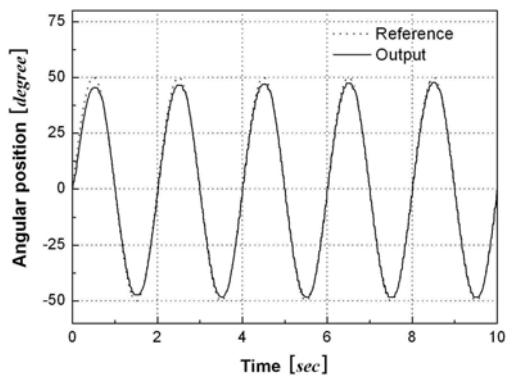


**Fig. 10 Reference and output signal**

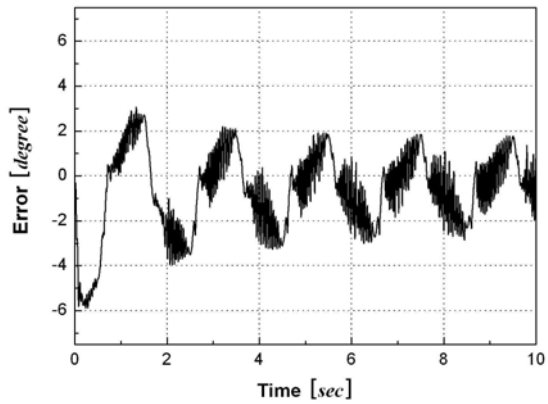


**Fig. 11 Error signal**

**Fig. 12 SMA valve with motor control**

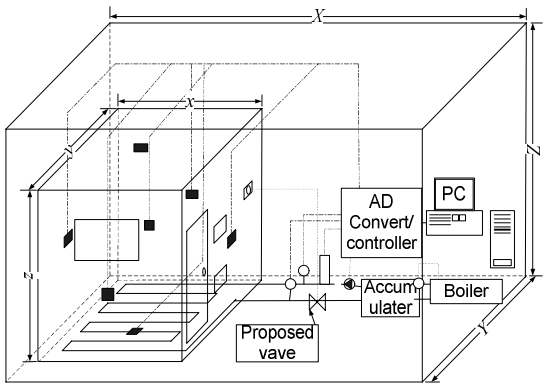


**Fig. 13 Test bed for proposed valve system**

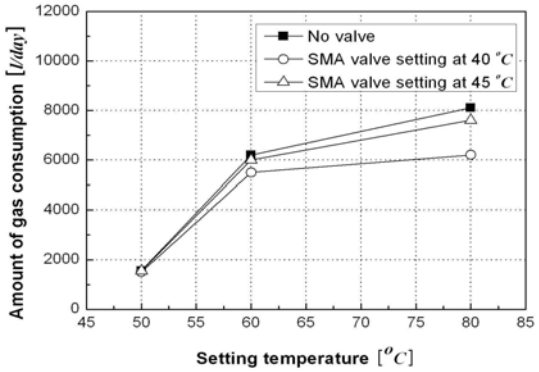


**Fig. 14 Amount of gas consumption per day**

## 3. Experiment

The proposed SMA valve and motor control parts are shown in Fig. 12. Based on the proposed valve system, the test bed for evaluate the energy saving is set as shown in Fig. 13. As shown in Fig. 13, the proposed valves are attached in the test bed. And the sensors for the temperature which is the inside and outside temperature of the room are also installed before and after valve. The temperature signals of temperature from the sensors are converted through the AD convert and monitored on the PC. The flow pressure is $0.3kg/cm^2$ in heat pipe. The tests are conducted with 3 different ways. The first is No valve, this case is not used valve, the second is that the SMA valve manufactured with actuating at 40℃ and the last is that the SMA spring is set in acting at 45℃. Fig. 14 shows the amount of gas consumption per day with and without the proposed valves and two different SMA valves. As shown in the result of experiment, the proposed valve system shows the 11~30% of energy saving effect in accordance with two SMA valves since the SMA spring is operated in the specified temperature and the additional hot water is not supply to the room. Even though SMA valve setting at 40 ℃ shows the best energy saving but since the proper room temperature depends on individual preference, the

additional study to find optimal temperature to satisfy the energy saving and individual preference should be researched.

## 4. Conclusion

The energy saving thermostatic valve is proposed in this paper and the performance of it is shown through experimental result. Also the remote control system is attached to the proposed valve to control the regulator handle which controls the disk to open for additional flow through the valve. Through the remote controller each valves for individual room can be controlled in the one place. Even though the effect of energy saving is shown through the floor heating system, the modification of the proposed valve can be also used to the radiator house heating system.

## Acknowledgement

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