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A study on CFRP based lightweight House deck structure design and configuration of Deck body connected IoT sensor data acquisition devices

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Abstract

In this paper, we designed a IoT(Internet of Things) sensor block embedded lightweight house deck structures that can be implemented using Carbon Fiber Reinforced Polymer(CFRP). Deck-Sensor interconnection interface block via IoT connectivity Hub that can mount external environmental sensors such as fire sensors on the Deck body itself was also proposed. Additionally we described the configuration of devices for data acquisition and analysis based on IoT environmental detection sensors that can be commonly installed and used on these deck bodies. On the other hand, received sensing data based monitoring user interface(UI) also developed and used for sensing data analysis for remote monitoring center. Through the implementation of such IoT-based sensor data transmission and collection analysis devices and UI software, this paper confirmed the availability of CFRP based lightweight House deck structure and possibility of CFRP deck-based IoT sensor data networking and analysis functions.

Keywords: *Carbon Fiber Reinforced Polymer(CFRP), Internet of Things(IoT), lightweight House, Deck. Sensor, R*

1. Introduction

Carbon fiber is a versatile and high-performance material that has numerous superier properties such as strength and lightweigh,stiffness,low thermal expansion, electrical conductivity, aesthetics, customization and design flexibility[1]-[4]. CFRP is also light, has excellent strength and elasticity, and has excellent corrosion resistance, so it has been used in the construction field for various purposes such as repair, reinforcement, replacement of rebar, and concrete reinforcement. CFRP can be manufactured and used in various forms such as plates, sheets, grids, and cables[5]-[8]. However, since carbon fiber reinforced plastic (CFRP) is a material

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made by adding epoxy resin to carbon fiber, although the material itself has the advantage of being applied in various fields as listed above, the components that make up the material epoxy resin itself is very flammable and vulnerable to fire[9][10], thus it has the limitation that it is not easy to use in areas sensitive to fire, such as exterior materials for buildings.

As a new approach to overcome conventional usage limitation of CFRP, we will design a IoT sensor block embedded Deck structures of CFRP-based lightweight houses using CFRP materials as exterior materials in this paper. As a special design solution to compensate for the fire-prone factors of CFRP materials, a structure including a Deck-Sensor interconnection interface block that can link IoT connectivity Hub and external environmental sensors such as fire sensors on the Deck body itself will also be proposed. As a follow-up processing device consist of various sensors including fire sensors with IoT communication interface block, (i.e., IoT connectivity Hub) will be connected Deck Body Furthermore, Sensing data processing hardware device block for subsequent processing linked to the sensors of the CFRP Deck Body will be implemented, which have the ability to transmit data from external environmental sensors, including fire detection sensors installed on the deck, to an external remote management center through the IoT connectivity Hub, and also will provides the ability to collect and analyze sensor data received from external remote centers. Finally We will show a implemented data processing hardware unit related sensing data analysis human machine interface (HMI) user interface (UI) for remote data management and monitoring center.

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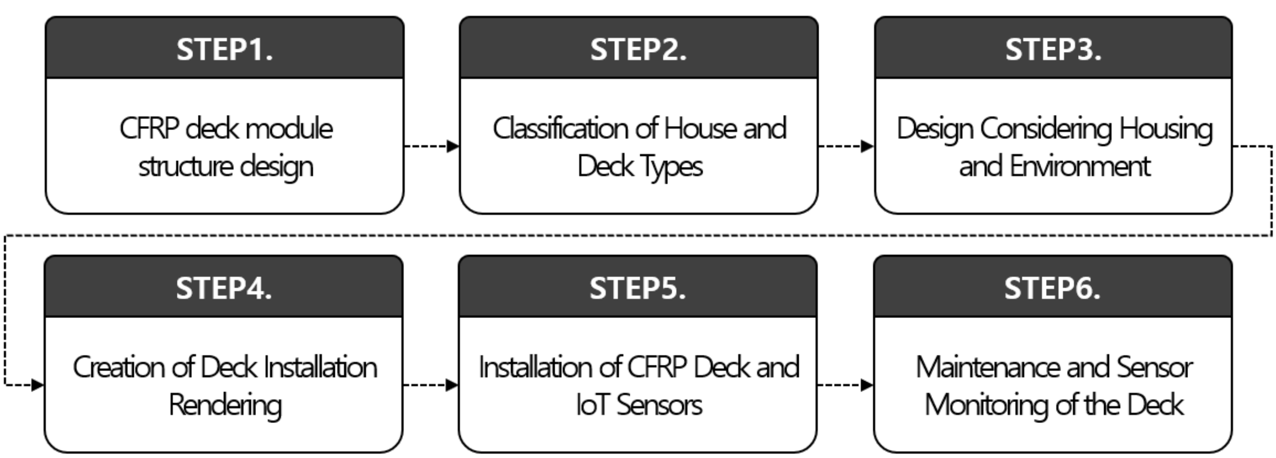
2. CFRP material based Lightweight houses Deck structures designs

In order to design CFRP material based Lightweight house Deck structures we establish design progress by using IoT sensor embedded Deck structure and monitoring characteristics as shown in Table1.

Table 1. Lightweight house deck design progress flow based on CFRP material



As a basic component we designed a basic CFRP deck module structure consist with CFRP deck surface and aluminum back frame joint as Figure 1. That is, CFRP material or CFRP GRID [5] generally itself has limitations in being used independently as an exterior material, therefore, in this study, we suggest a CFRP exterior material structure joining a lightweight and strong aluminum back frame to support it. Also, depending on the situation in which the deck is constructed, the back frame material can be replaced with other materials such as steel or wood instead of aluminum. Then, we considered lightweight house classification and deck types based on a basic CFRP deck module combining and expanding. We designed four deck types commonly used in lightweight houses as shown in Figure 2, where the texture of the deck material was considered with the unique color and texture characteristics of CFRP materials.

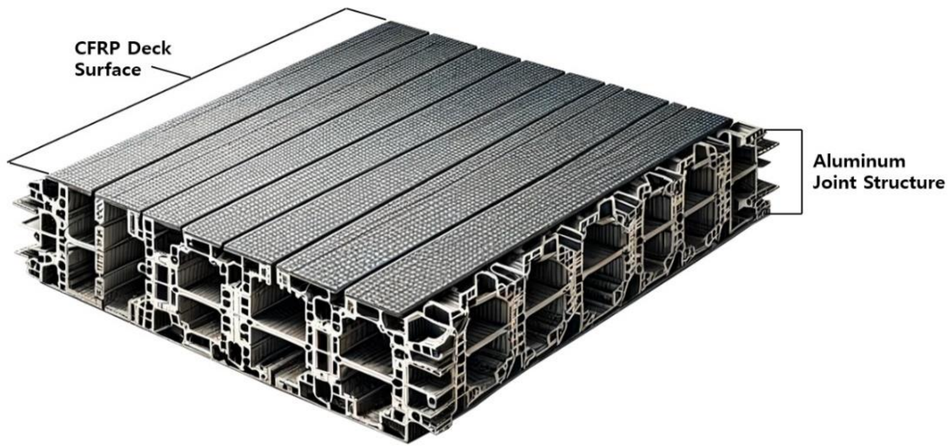


Fig. 1 Designed CFRP deck surface and aluminum back frame joint structure

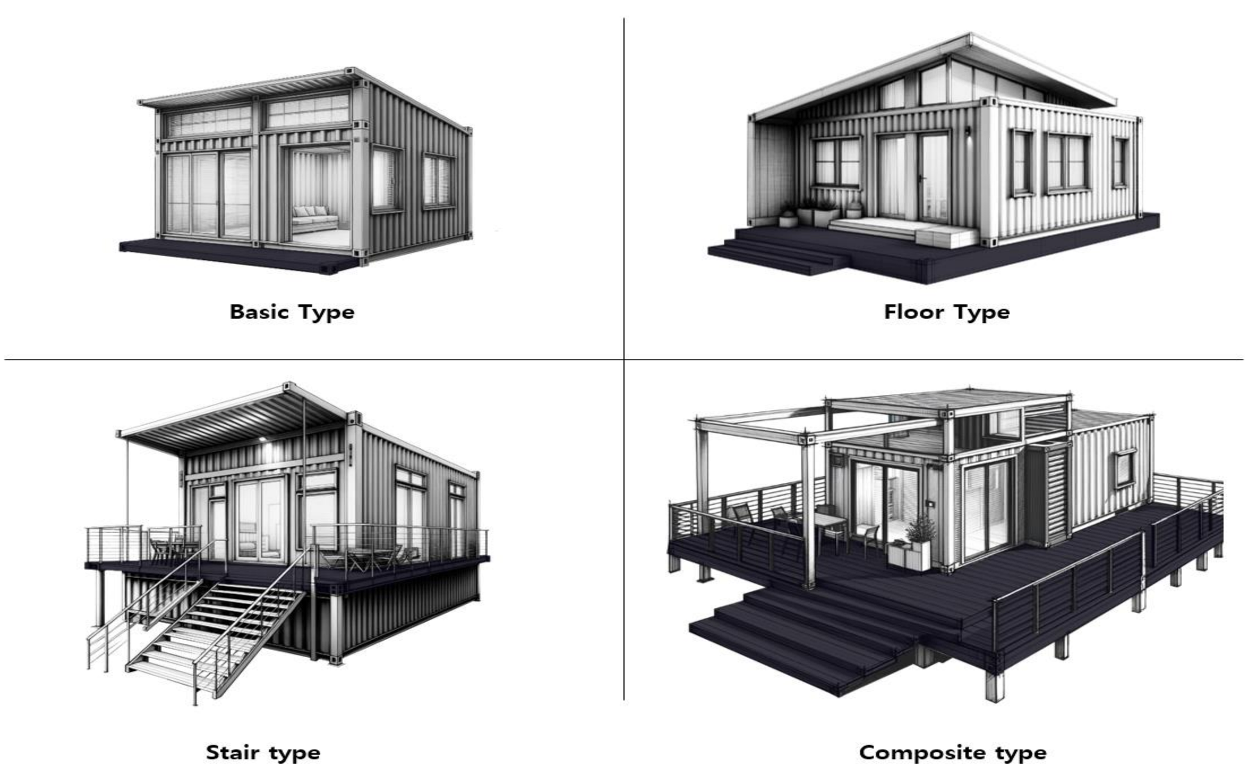


Fig. 2 Design examples according to Lightweight houses classification & Deck Types

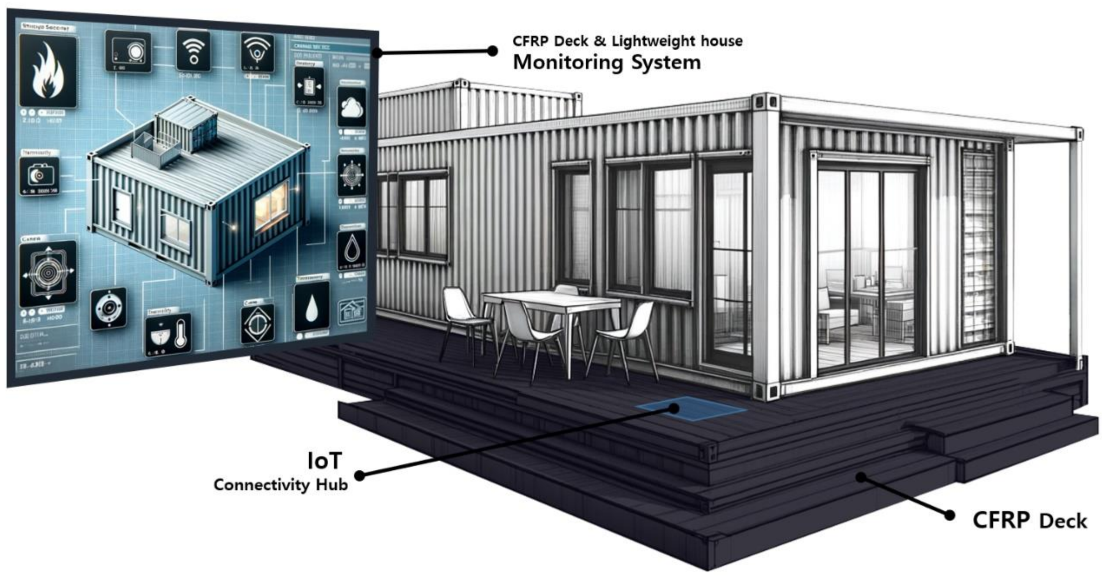


Fig. 3 IoT Hub included CFRP Deck structures design example

On the other hand, as shown in the Figure 3, a specific space for sensors and IoT connectivity Hub that easily combine external environmental sensors and IoT communication devices with Deck was designed in a specific space (upper part, etc.). In this study, as basic external environmental sensors that can be installed in the deck area, fire sensors for fire prevention, temperature and humidity sensors, and camera sensors for on-site environmental monitoring were considered as Figure 4.

Fig. 4 Deck connected External environmental sensors example

3. Sensor data monitoring device Configuration

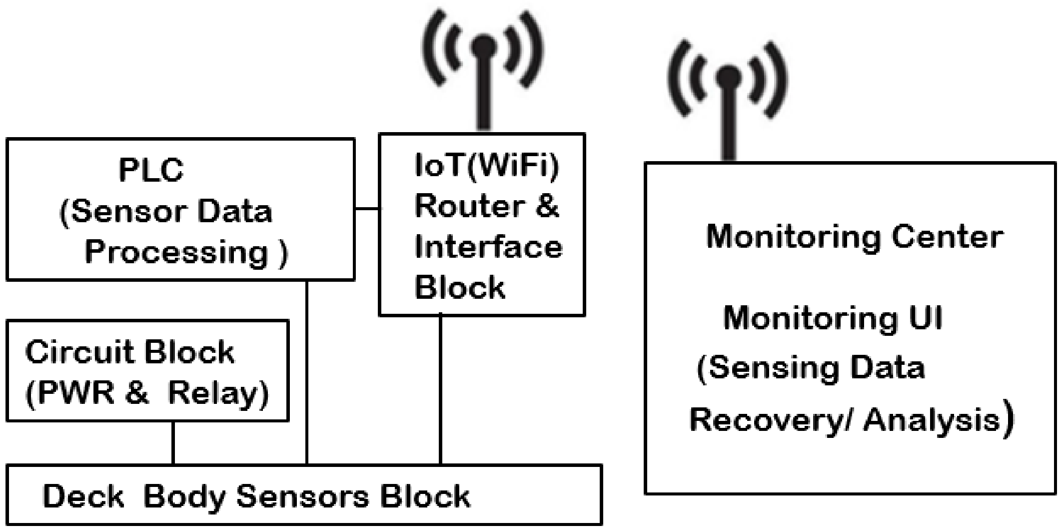


Fig.5 TRx data processing flow for Deck body connected Sensors

Figure 5 shows the data processing flow of Deck body & Sensor based transmitter(Tx) and receiver(Rx). The sensor block attached to the deck body is linked with a circuit block that supports programmable logic controller(PLC) and IoT parts, and the data sensed from the deck is transmitted through the PLC and IoT device. On the other hand, monitoring center get recovered sensing data through the IoT block and monitoring the deck environment remotely through analysis of sensor's UI data and special event detection functions.

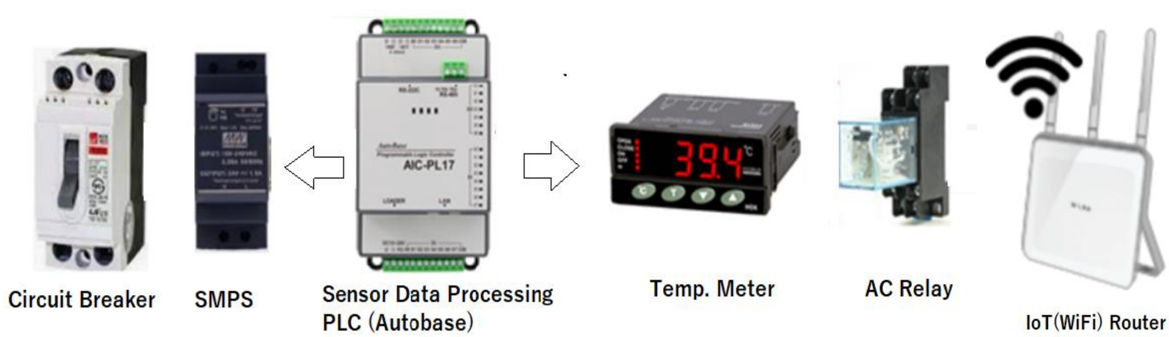
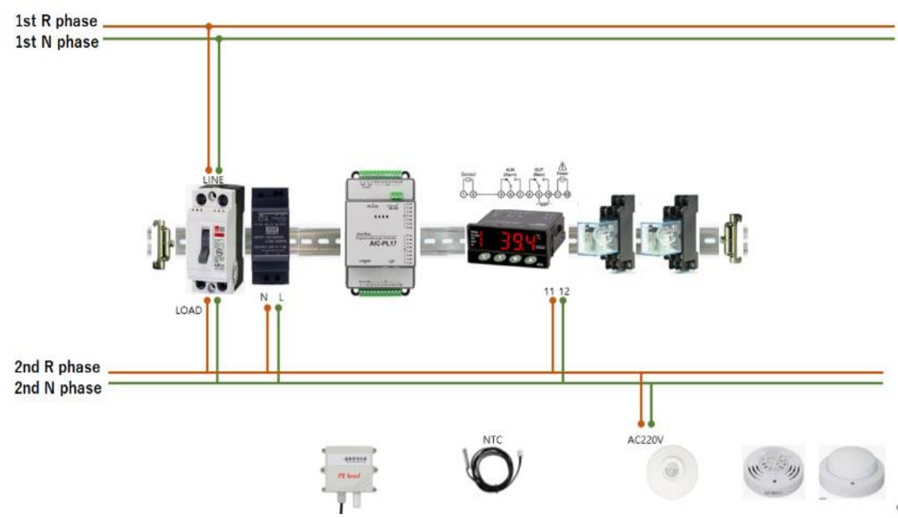
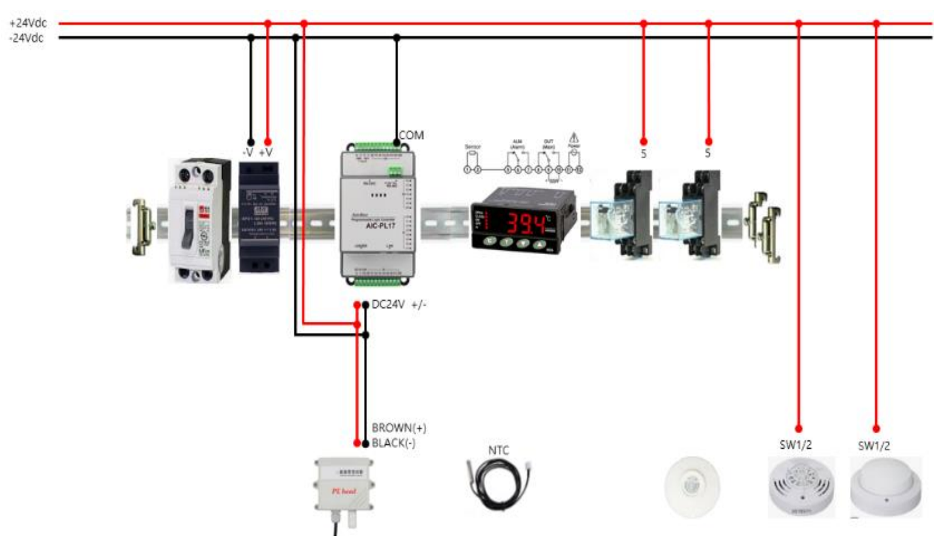


Fig.6 Deck body connected Sensor data processing devices and IoT Router

Figure 6 lists sensor data processing devices and IoT routers that can be connected to the deck body. Based on the devices listed in this way, Figure 7 shows the connection structure of above each device, taking into account the form in which the environmental sensors attached to the CFRP deck body are connected to the sensor data processing block formed by PLC and connected to alternating current(AC) and direct current(DC) power in the deck space.



(a) AC power line connected case



(a) DC power line connected case

Fig.7 Power line connected sensor & sensor data processing block example

That is, Figure 7 shows the configuration diagram of the sensor data actually connected to AC power and DC power in order to conduct the Deck body connected Sensor connected TRx data processing experiment presented in Figure 7. In the case of AC power, externally applied power is converted to DC power through SMPS through a circuit breaker and used, but in the case of some industrial environmental sensor modules, AC power may be used as is.

4. Test result and analysis of sensing data processing block & monitoring UI

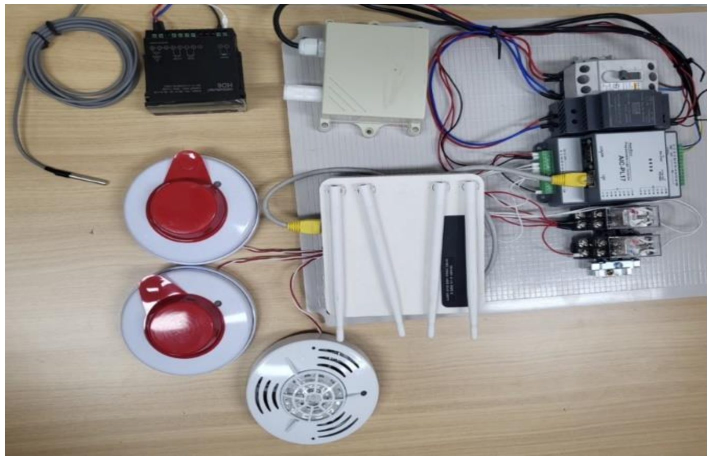


Fig.8 Implementation result of sensor data processing block example

Based on the structures described above, Figure 8 shows the CFRP deck body-attached environmental sensors connected to the sensor data processing block formed by PLC, and the test hardware(H/W) configuration results consisting of the PLC block, circuit block, relay, etc. .

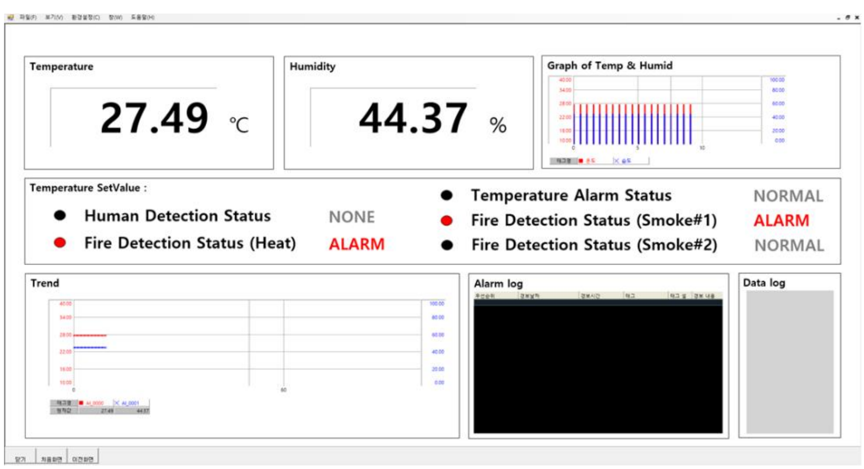


Fig.9 Implemented Sensor data analysis & monitoring UI

Figure 9 show a implementation result of sensor data monitoring UI. The sensor data analysis and monitoring UI program shown in Figure 9 is installed on the monitoring center PC, and can remotely monitor the situation in the field through analysis of data transmitted from the environmental sensor installed on the CFRP deck, and detect abnormal situations in the field.

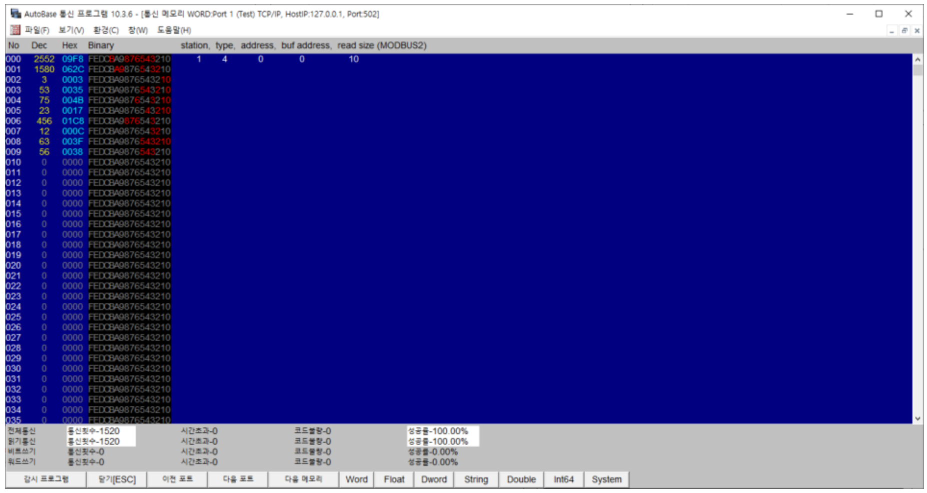


Fig.10 IoT Sensor Data Recovery result

One the other hand, Data from the environmental sensor attached to the deck body is sent to the sensor data processing block(PLC), and PLC convert sensor data to Modbus communication packet data and transmit to the monitoring center through an IoT device. One part of monitoring UI screen could shows an IoT sensor data recovery function as shown in Figure 10. Through the experimental results shown in Figures 7 and 8, sensor data connected to the deck body is transmitted through the IoT devices, and the monitoring UI in Figure 10 shows Rx device's perfect data recovery function without bit error clearly. Additionally, Monitoring UI menu basically consists of alarm, trend, and log functions to enable immediate remote action when detected by a sensor as shown in UI menu in Figure 10. The sensor data analysis and monitoring UI screen is largely divided into three parts. Each part consists of a monitoring part for analog sensing data, a monitoring and operation status identification part for digital sensing data, and a trend and alarm/log part.

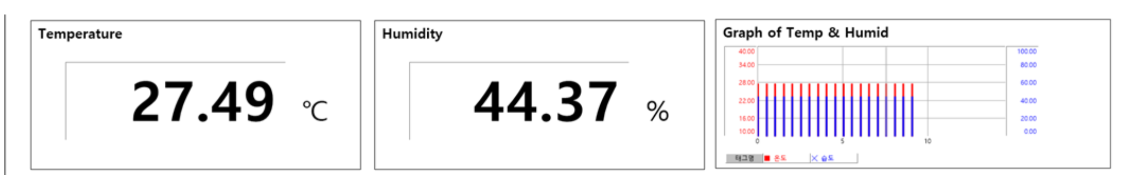


Fig.11 Temperature and humidity sensor data monitoring part block

As shown in Figure 11, Temperature and humidity data, which are analog sensing data, are expressed in numbers so that they can be checked intuitively, and the change trend of the data can be confirmed through a bar graph.

Fig.12Digital Sensing monitoring part block

Digital Sensing monitoring part block in Figure 12 expresses the operating state through a circular image indicating the state at the front of the data name along with the name representing each data, and states such as normal/alarm at the end of the data name, and in particular, abnormal states are marked in red and expressed for easy identification. Through this, operators were able to immediately monitor the on-site situation and identify abnormal conditions.

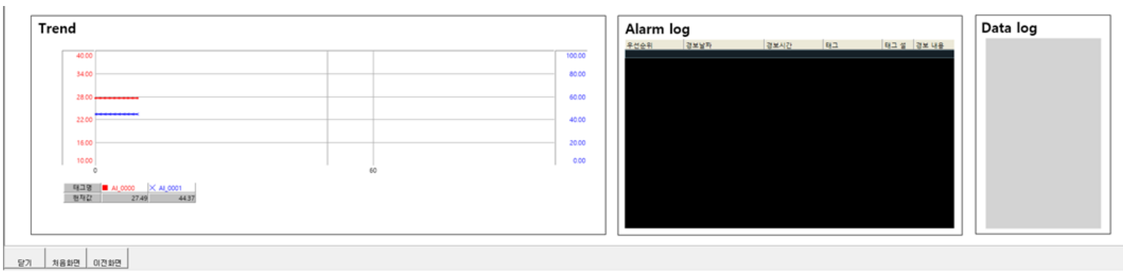


Fig.13 Trend, Alarm log, Data log monitoring part block

In Figure 13, A trend graph was created to identify the history and trends of analog data through trend analysis. The alarm log is designed so that the alarm occurrence/release details and occurrence/release time can be identified. It is designed to check changes in analog sensing data and digital sensing data through data logs.

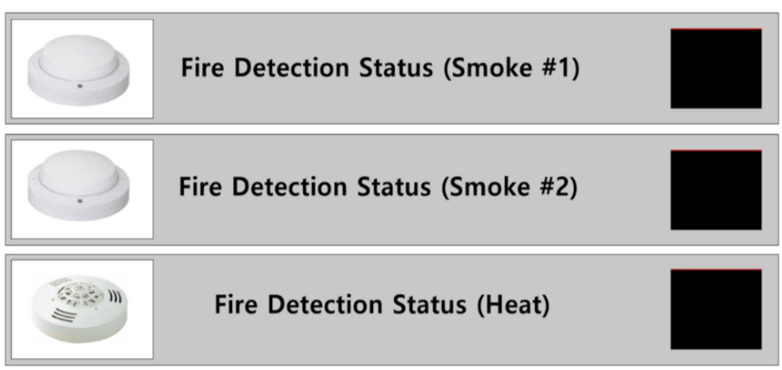
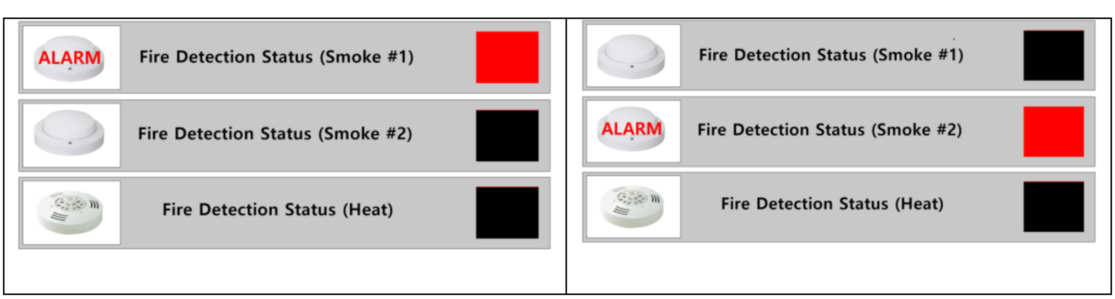


Fig.13 Fire Detection Status modes



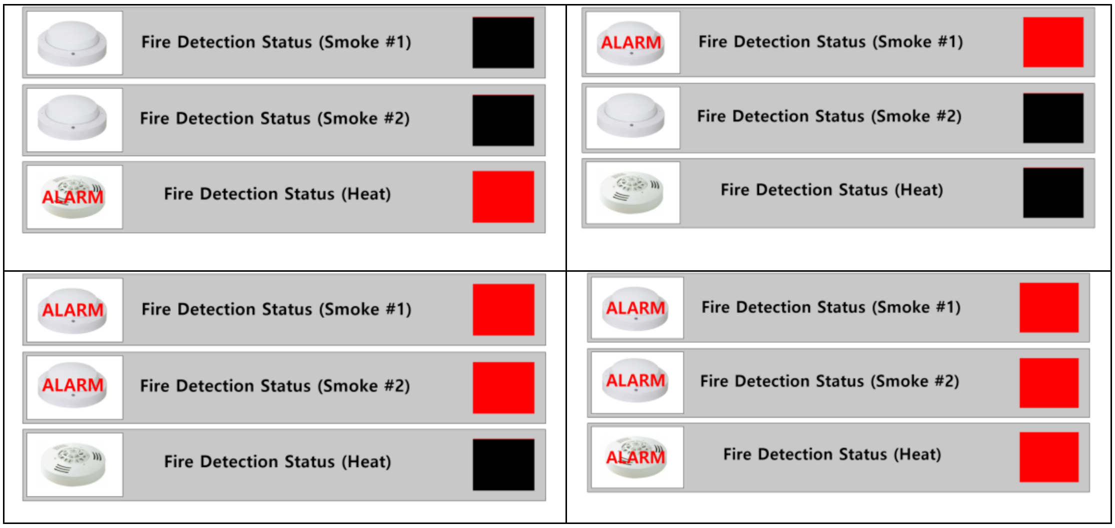


Fig.14 Fire Detection connected Sensor alarm event cases

Figure 13 is one of the items implemented in the monitoring UI screen in this paper. Among CFRP deck-based sensors, three types of sensors for fire detection are prepared by reflecting the flammability characteristics of CFRP materials, and alarms are generated when these sensors operate. A rectangular UI icon was designed to express the mode. Figure 14 shows the alarm mode according to the operation case of the three types of fire detection sensors. In other words, when a sensor is detected, the word alarm is displayed on the left sensor symbol on the monitoring screen, and the rectangular UI icon changes to red. We implemented an operation function on the real-time monitoring UI for fire detection events based on these various fire detection sensors.

Conclusion

In this paper, we designed a IoT sensor block embedded Deck structures of CFRP-based lightweight houses as examples for using CFRP materials as exterior materials. As a special design solution to compensate for the fire-prone factors of CFRP materials, a structure including a Deck Sensor interconnection interface block via IoT connectivity Hub that can mount external environmental sensors such as fire sensors on the Deck body itself was also proposed. In addition, a hardware device for subsequent processing linked to the sensors of the CFRP Deck Body was implemented, which has the ability to transmit data from external environmental sensors, including fire detection sensors installed on the deck, to an external remote management center through the IoT communication interface block, and also provides the ability to collect and analyze sensor data received from external remote centers. Therefore, through the implementation of such IoT-based sensor data transmission and collection analysis devices, this paper also confirmed the possibility of collecting CFRP deck-based sensor data and the basic implementation of remote transmission and remote data management functions of IoT-based sensor data.

Acknowledgement

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