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Development of a Smart System for Measuring Strain Levels of Natural Gas and Petroleum Pipelines on Earthquake Fault Lines in Türkiye

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***Abstract*—**Load changes occur on natural gas and oil pipelines due to natural disasters. The displacement of the soil around the natural gas and oil pipes due to situations that may cause erosion, such as earthquakes, landslides, and floods, is the source of this load change. The exposure of natural gas and oil pipes to variable loads causes deformation, cracks, and breaks in these pipes. Such cracks and breaks can cause significant damage to people and the environment, including the risk of explosions. Especially with the examinations made after natural disasters, it can be easily understood which of the pipes has sustained more damage in those quake-affected regions. It has been determined that earthquakes in Türkiye have caused permanent damage to pipelines. This project was initiated in response to the identification of cracks and gas leaks in the insulation gaskets placed in the pipelines, especially at the junction points. In this study, a SCADA (Supervisory Control and Data Acquisition) application has been developed to monitor load changes caused by natural disasters. The developed SCADA application monitors the changes in the x, y, and z axes of the stresses occurring in the pipes with the help of strain gauge sensors placed on the pipes. For the developed SCADA system, test setups in accordance with the standards were created during the fieldwork. The test setups created were integrated into the SCADA system, and the system was followed up. Thanks to the SCADA system developed with the field application, the load changes that will occur on the natural gas and oil pipes are instantly monitored, and the accumulations that may create a load on the pipes and their surroundings are immediately intervened, and new risks that may arise are prevented. It has contributed to energy supply security, asset management, pipeline holistic management, and overall sustainability in the industry.

***Keywords*—**Earthquake, natural gas pipes, oil pipes, voltage measurement, landslide.

I. Introduction

NATURAL gas and oil are transported by means of pipes placed underground in order to prevent losses that may occur due to environmental events [1], [2]. Natural gas and oil pipes located underground can be exposed to natural disasters [3]-[5]. Natural disasters such as landslides and earthquakes cause damages, breaks and cracks in natural gas and oil pipes [6]-[8]. Cracks and breaks in the network pipes may cause natural gas and oil spills to the environment [9], [10]. Leaks that may occur in the network pipes damage the environment with explosions and fires. The damage to the environment causes financial and reputational losses [11], [12]. The extent of the environmental damage can be seen through the events. Events in South Africa, the United States of America (USA) and Istanbul can be given as examples of explosions caused by natural gas leaks [13]-[15]. Therefore, it is of great importance to learn beforehand about the damage in natural gas and oil pipes and to repair them locally [16], [17]. Through the Izmirgaz Natural Gas Distribution Inc. and Karabuk University university-industry cooperation, "Development of a Smart System for Measuring Strain Levels of Natural Gas and Petroleum Pipelines on Earthquake Fault Lines in Türkiye ", we can learn locally about the damage that occurs in natural gas and oil pipes. With this project, natural gas and oil spills that may harm the environment can be prevented, and this will reduce environmental financial and reputational losses.

II. Material Method

In the study, four different strain gauge sensors were placed on natural gas and oil pipes. The data collected by the voltage meters are measured with data collectors (data loggers) and stored in the system memories. The system computer that the system has in itself allows us to monitor the stored data and is used in the control of the system. The values measured by the sensors represent the stresses in mV [18]-[20]. The applied load values are measured with the data coming from the strain sensors to the SCADA system. After the measurement process of the sensors, the force values are calculated by conversion. The system sends a warning depending on whether the calculated values are within the nominal value range or not. Nominal values may show different values in certain regions. For this reason, the nominal values of the locations can be measured separately, and they can provide warnings when necessary. System data can be followed over the internet and SCADA computers. The sensors that read the data, transmit the data to the data readers so that it can be recorded in the system and read from SCADA computers. Then, the voltages of the network pipes in the system are measured and the load status is checked. If the load applied to the network pipes by environmental factors after natural disasters is above the strength of the network pipes, the system transmits them as a warning to the companies that transmit through natural gas and oil pipes. In this study, considering the thickness of the network pipe, the burial depth and the altitude values, the voltage

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conditions of the network pipelines at different points were examined with four different strain gauge sensors, and the load conditions on the network pipes were evaluated. In the study, cyber security measures were also considered, and only authorized users were allowed to monitor and interfere with the system from the outside.

Natural gas transmission is provided by steel network pipes to the RMS stations where the pressure values are reduced for distribution to local areas. The burial depths according to the diameter values of the steel network pipes according to the standards are shown in Figs. 1 and 2.

Diameter (inch)	Minimum buried depth-minimum limit (m)	Maximum buried depth-maximum limit (m)
8	0.5	9.4
12	0.8	4.8
16	0.9	3.5
20	1.1	2.4
24	1.5	1.8
28	1.3	2.0
30	1.0	2.8

Fig. 1 Safety embedment depth according to 60° abutment angle [21], [22]

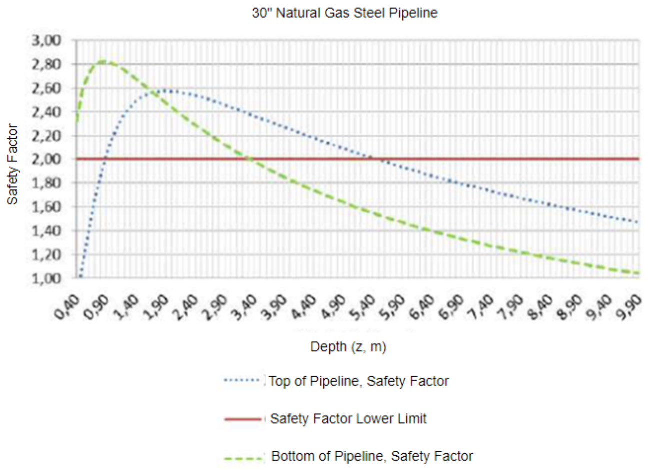


Fig. 2 30" Natural Gas Steel Pipe embedding depth safety factor [21], [22]

The embedding depth varies according to the load that may occur on the network pipes, the place where it is used, the diameter it has and the wall thickness. In the literature, the burial depth of the network pipes is standardized according to the diameter of the pipe to be used [22].

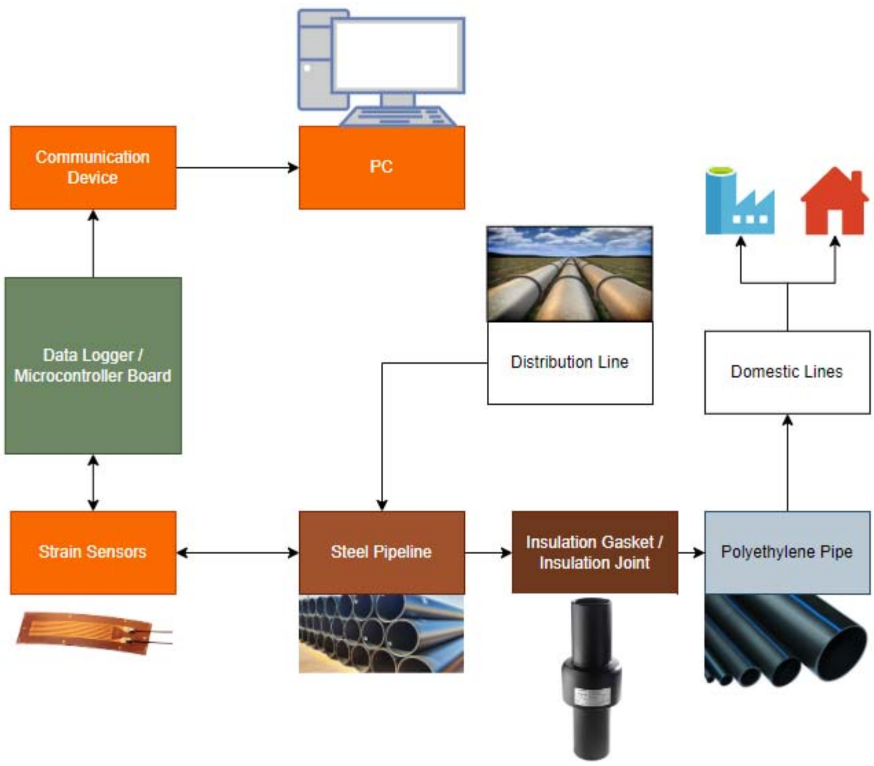


Fig. 3 Connection diagram of sensors, natural gas mains and data transfer system

Fig. 3 shows the diagram and connections of the test system that has been studied. As can be seen in Fig. 3, in order to lower the bar that goes to the pipes in the distribution on the steel network pipes from the distribution line, a mechanism has been set up in the regions close to the insulation gasket notes found in the RMS stations. The set up was measured with tension meters. The data were transmitted to data loggers to collect and transferred to the system computers with communication devices and followed up.

III. Results and Discussion

Investigations were carried out for the required period of time. System data are recorded in databases located in Karabuk and Izmir. The data are accessible to remote authorities. However, it is closed to outside interference within the scope of cyber security.

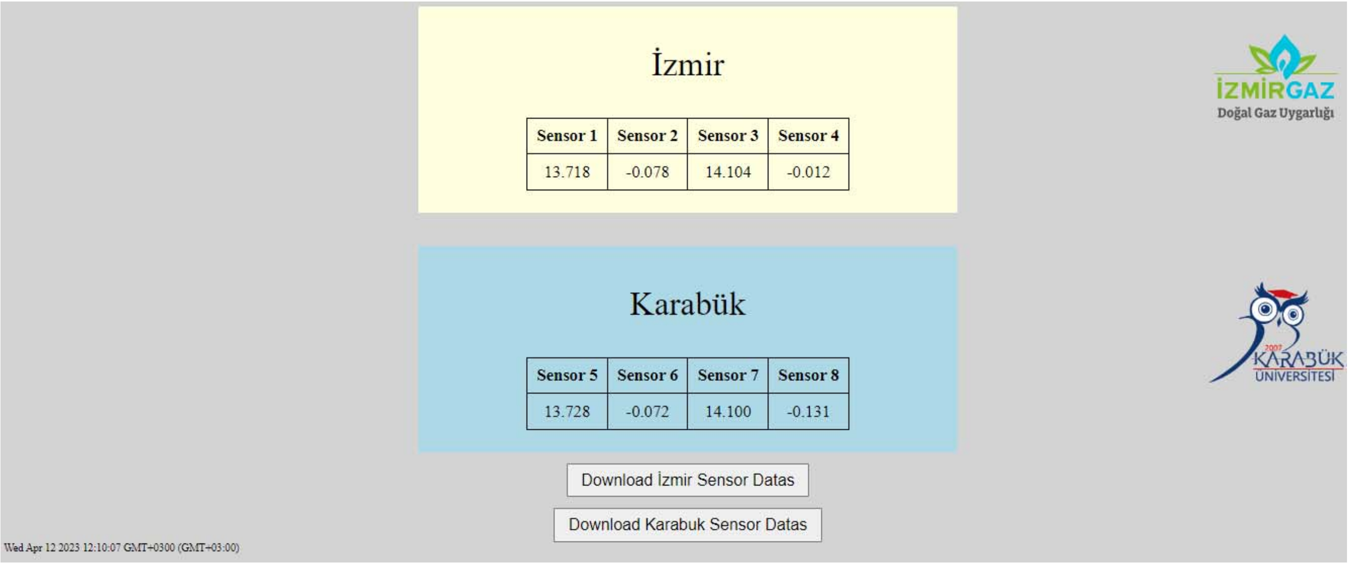
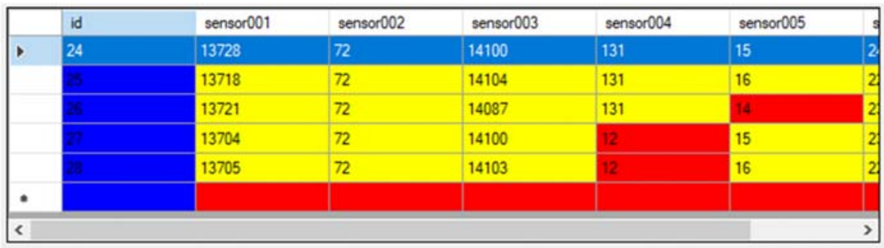


Fig. 4 Interface that can be tracked on the Internet



id	sensor001	sensor002	sensor003	sensor004	sensor005
24	13728	72	14100	131	15
25	13718	72	14104	131	16
26	13721	72	14087	131	14
27	13704	72	14100	12	15
28	13705	72	14103	12	16

Fig. 5 Monitoring of the data registered in the database via SCADA computers

The values obtained are the mV equivalent of the voltage meters. With the calculations made, load values in Nm can be obtained.

In the study, in the image shown in Fig. 5, sensor004, gives instant warnings to the company that distributes gas or oil, depending on the load changes that have occurred in the network pipes. Warnings can be seen on the screen in red as a result of the R&D work. At the same time, system computers can give voice warning to users. Depending on the system speed and the performance of the devices in the system, incoming data can transmit data at intervals from second to second, minute to minute, hour to hour or more.

In the R&D study, the stresses that occur as a result of the loads applied to the pipes were measured by the sensors and the obtained values were compared with the nominal values, and warnings were sent to the users for the values outside the nominal values. No heavy damage was observed during the load values applied to the network pipes in the test setup. The applied load values were applied in different sizes. With the study, it is expected that the life of the network pipes will be extended by measuring the changes in the network pipes at specified intervals. The investigations were made for a certain period of time, and the damage to the pipes in the system was measured. It is thought that the follow-up of the obtained data will cause an extension in the life of the pipes.

IV. Conclusion

The system work set up to collect data was audited for the specified period and the data were recorded. During the study, the load changes in the network pipes were evaluated. Loads that will cause damage or destruction in the network pipes have been detected. However, there was no visible heavy damage to the pipes during the study. Strain gauges transmit all stress values at all applied loads. It was observed that the yield strength curves of the network pipes remained in the plastic deformation region in the obtained network pipe stress values. Monitoring over a longer period of time is necessary to observe changes in the material's lifespan. The R&D work is ongoing. In subsequent stages, it is planned to compare the behavior of the loads applied in the test setup against those applied in the simulation environment. With this comparison, the similarity of the values of the simulation and the actual test setups to each other will be checked. In this way, the cost of the tests to be carried out in larger lands and larger projects will be reduced.

In addition, the answer to the question of where the test setup should be established will be found.

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