Development of Accessible Pedestrian Signals (APS) with Piezoelectricity

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Abstract – At signalized intersections with heavy traffic, illuminated pedestrian crossings are applied for pedestrians to cross safely. At this stage, the green light is activated according to predefined times or signals from Accessible Pedestrian Signals (APS). Thanks to the pedestrian signals, the system activates only when there are pedestrians, and the flow of traffic accelerates as the vehicles do not have to stop when there are no pedestrians. APS are devices that give audible, vibrating and visual warnings so that all pedestrians can cross safely. An APS is a device that conveys information about pedestrian timing in a non-visual form, such as audible tones, spoken messages, or vibrating surfaces. The purpose of the signal pedestrian signals is to inform the intersection control device by detecting pedestrians on the highway section where the drivers are traveling at high speed, where there are heavy vehicle crossings and where there is no over and underpass facilities, and to make the transportation easier for the pedestrian to pass. In this study, it is aimed to design an APS at signalized intersections by using piezoelectric sensors. It is aimed to develop a completely domestic design by investigating the benefits, deficiencies, applicability and contributions of the planned system compared to the existing APS.

Keywords – Piezoelectric Sensor, Clean Energy, Signalized Intersection, Accessible Pedestrian Signal, Pedestrian Crossing

I. INTRODUCTION

Today, with the increase in population, the need for energy is increasing in all areas of life. For this reason, the importance of the use of alternative energy sources such as wind, solar, hydroelectric and geothermal is increasing day by day, and the search for environmentally friendly and sustainable applications is gaining momentum. One of the prominent aims of this study is to design an environmentally friendly accessible pedestrian signal that does not need an additional source for electrical energy and provides the energy source from piezoelectric materials.

Coordination between motor vehicles and pedestrian crossings is provided by traffic lights at the points where traffic signaling systems are located. Turning on the green light for motor vehicles and pedestrians is carried out either over predefined automatic times or by receiving the necessary signal using the pedestrian signal. Pedestrian presence can be understood in line with the signal coming from the pedestrian signal. This signal is created by pressing the pedestrian signal. Within the scope of the study, it is aimed to design an APS by using piezoelectric materials in order to eliminate the problems at signalized intersections. For this purpose, it is aimed to develop a completely domestic design that does not require an additional source for electrical energy, is more environmentally friendly and more economical than existing technologies.

A. *Definition and Purpose*

An APS is a device that conveys information about pedestrian timing in a non-visual form, such as audible tones, spoken messages, or vibrating surfaces [1].

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B. *History*

Although there were reports of audible pedestrian signals in the USA as early as 1920, they are not included in US standards and regulations [1]. It has been widely used in Japan and Sweden since the 1960s. In 1976, the first significant research on this topic was conducted in New South Wales, Australia. This research forms the basis of APS systems used today. Mass marketing of accessible pedestrian signals was first done in the 1970s in the USA. In 1988, significant research was conducted on APS.

Fig. 1 The first APSs made in the USA [1]

In Turkey, the first field application was carried out in 2005 at SSK Okmeydanı Pedestrian Junction numbered 2218 in Istanbul. Against the Covid-19 virus, many of these pedestrian signals in Istanbul are now made contactless and equipped with the 'photocell' feature [2].

Fig. 2 Contactless pedestrian signal [2].

C. *Benefits of APS*

Studies have found that APSs improve crossing performance by visually impaired pedestrians. Also, pedestrians can cross more quickly at intersections with APS, access security of pedestrians increases with APSs and waiting times at intersections are minimized.

Fig. 3 Accessible pedestrian signals [1].

D. *Limitations*

The difficulties and economic disadvantages of the existing accessible pedestrian buttons can be listed as follows; pedestrian buttons are mounted on signal poles at a height accessible to pedestrians. This gives malicious individuals easy access to the device. They created especially for disabled individuals, provide audible warnings for the visually impaired. These warnings work continuously for 24 hours, including the standby mode, during the red and green periods for pedestrians. This situation causes negative effects on both the shop and the residents in the area and may cause physical attacks on the device from time to time. Therefore, pedestrian signals and especially disabled pedestrian buttons are produced to be resistant to physical impacts. Pedestrian buttons in the outdoor environment must be resistant to rain and snowfall, so they must not pass water into their body. Therefore, they are generally produced in accordance with the IP68 standard and are tested in accordance with this standard. They receive the required request by pressing the button on them. In other words, the user makes the necessary request himself by touching the device. The need for

pedestrians to make requests directly by pressing the button causes hygiene problems for many users. Since the pedestrian has direct contact with the button, the device must either be manufactured from an electrically insulating material, electrically isolated, or operated with a low voltage (less than 50V). This situation necessitates the use of a transformer in the system in order to obtain low voltage.

The mounting of the device on the signalized pole and the fact that the fixation point on the pole varies according to the junction place increases the installation workmanship and damages the pole (the galvanized texture of the pole and the paint if any) due to the necessary screwing on the pole. Although no-signal technologies (infrared, photocell, camera systems, etc.) have started to be used due to the Covid-19 pandemic, this technology is not efficient on rainy or snowy days when the environment is dark, and visually impaired citizens cannot use this technology in line with their needs. Extra electrical energy is needed for the system to work. There is no domestic brand in APS technology.

In addition, pedestrian buttons designed for disabled citizens in general cause usage problems for many pedestrians in this situation; the difficulty of a visually impaired citizen in locating a button designed in a relatively small size, a disabled citizen without arms cannot press the button, the difficulty experienced by a disabled citizen sitting in a wheelchair in accessing the button, the inability of a paralysed citizen to reach the button due to the inability to raise his arm, etc.

In addition to these problems, there are some problems with the existing system for citizens without disabilities; difficulty pressing a button with full hands (from shopping, holding a stroller, etc.), having citizens who do not know how to press the button, inability to detect whether the button has been pressed (the pedestrian button is quite small and can be easily closed by a person).

II. Developments In Piezoelectricity

The word “piezo” means “pressure” in Greek. The piezoelectric phenomenon was discovered by the 18th century French physicists Jacques and Pierre Curie. Piezoelectric property can convert a mechanical energy into electricity or vice versa, electrical energy into mechanical energy. Piezoelectric property is the ability of the material to change an electric field or electric potential as a result of mechanical pressure applied to certain materials (especially crystals and certain crystals; bone).

Lead-zirconium-titanium (PZT) ceramics are generally used in piezoelectric materials. Non-symmetry crystals are used to create this effect. Zinc Oxide (ZnO), Tourmaline, Quartz (SiO2), PVDF (Poly-vinylidine-chloride) and Barium Titanate (BaTiO3) are some of the materials used. The working principle of Piezoelectricity is shown in Figure 2.

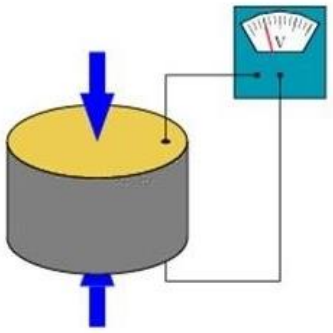

Fig. 4 Piezoelectric working principle [3]

A. *Usage Areas of Piezoelectric Materials*

The piezoelectric effect is widely used in daily life and industry; in ultrasonic applications such as ink cartridges of many computer printers, intrusion detectors and alarms, in applications that measure such as microphones, precision scales, accelerometers, motion sensors, it is used in headphones, pickup cartridges, lighters and lighted sneakers. In addition, it is stated that piezo-electric energy provides continuous, stable and long-term clean energy, and it is suggested that the electrical needs of the electronic equipment that the transportation infrastructure will need can be met with this type of energy [4].

B. *Use of Piezoelectricity in Road Infrastructure*

Electric energy production was investigated by using vibration-based piezoelectric material, which is intended to be used in rail systems and highways, and a prototype model was created [5].

An alternative system in road traffic regulation: vehicle counting smart concrete (using piezoelectric sensors) has been applied. Since the sensors used in traffic counting systems today are damaged quickly and these systems are more expensive, it is thought that vehicle counter smart concrete is a system that can distinguish and count vehicle types according to their loads and can be a good alternative to other

sensors used. Piezoelectric material embedded concretes were used in the study [6].

Electricity generation from piezoelectric materials was investigated at the Technopark Station, located on the metro line to be built between Sabiha Gökçen Airport, Kurtköy. There is a serious energy potential in metro systems, as there is intense passenger movement along the route of getting off the vehicle and exiting the station, getting off the station and getting into the vehicle. In the study, the amount of energy produced and which systems it will be transferred to were investigated, and the turnstile area in a station area was energized with a renewable energy source [7].

It is aimed to obtain energy from pedestrian movement on piezoelectric materials in Agartala city, India. The results of the sensitivity analysis in the study show that the pressure level and walking speed significantly affect the voltage generation. It has been determined that the energy produced by this process can be stored in supercapacitors that meet small energy requirements such as lighting a small powerful LED light at the roadside, charging mobile phones [8].

In a study, the issue of creating pedestrian areas where safety and comfort is provided, especially in areas where pedestrians are high in big cities, was investigated. In this context, it is aimed to make the area an independent power source by using piezoelectric sensor technology in energy conversion and calculating the average power in pedestrian steps. In this way, it was also aimed to attract the people to walk on the pavement [9].

III. Materials and Method

At the stage of the study, a box will be designed through which we will obtain energy with the passage of pedestrians. Here, energy production will be provided by piezoelectric materials that will be placed under the floor. Piezo means pressure. Some metals and minerals have piezo characteristics. In other words, if a pressure is applied to them, they generate a small voltage. Pedestrian presence can be detected without pressing any signal with the piezo materials to be placed under the ground at the traffic signalized intersection points where the pedestrians are waiting. Based on this information, a box will be designed to generate energy. After this box was placed under the ground, three different scenarios were performed on which the sand would be placed as 5cm, 10cm, 15cm. On the sand, cobblestones will be placed. The parameters that will affect the design are given in Table 1.

Table 1. Parameters for structural design

Materials	**Piezo Items (amount)**	**Height (cm)**	**Pedestrian Weight (kg)**
Sand (5cm)	4	1	30
Sand (5cm)	8	2	100
Sand (5cm)	16	3	500
Sand (10cm)	4	1	30
Sand (10cm)	8	2	100
Sand (10cm)	16	3	500
Sand (15cm)	4	1	30
Sand (15cm)	8	2	100
Sand (15cm)	16	3	500

IV. Results

Within the scope of the project, it is aimed to design an APS using piezoelectric materials. For this purpose, it is aimed to develop a completely domestic design that does not need an additional source for electrical energy, is more environmentally friendly and more economical than existing technologies. Underground application with piezo materials is more suitable than outdoor conditions. Underground installation, where pedestrians cannot directly contact, will eliminate problems such as malfunctions and being affected by physical impacts. Again, this will eliminate the extra costs of being exposed to physical impacts and outdoor conditions. The fact that it does not need any assembly on the pole eliminates the damage to the pole during the assembly, and there is no need for a pole. Pedestrians do not need to press a signal for presence information, just one click on the marked area on the ground will be sufficient for the required demand. The defined area on the ground can be revised as desired according to the way the piezo materials are laid on the floor. As with pedestrian signals, the need to reach a single point and press the button from there is eliminated. Since its installation is completely under the ground, it does not cause visual pollution. Since the piezo material itself converts the pressure effect into electrical energy, it does not need an extra energy source. The fact that piezo materials are natural and abundant in nature not only reduces the price of the product, but also shows that it is environmentally friendly. The absence of direct contact with the hand does not cause a hygienic problem in the product.

V. Discussion And Conclusion

In the study, the mechanical energy generated by the presence of pedestrians is transformed into electrical energy thanks to the piezoelectric materials placed under the floor. In this way, an economical product will be developed in the new system that does not require an additional electrical energy from outside. It is the first in this field to be designed with completely domestic materials.

Many conveniences that the new system will bring are as follows: to be economical, does not harm nature, easy to install compared to other devices, no need for signals in detecting pedestrians, pressing on them is sufficient to receive a request, it does not need any energy source during its operation, being more protected from possible physical impacts and outdoor conditions compared to its current examples, configuring the demand region as desired, ease of use for people with disabilities.

Conflict of Interest Statement

There is no conflict of interest with any institution or person within the scope of the paper, and all information and design parameters taken from the preliminary studies in the master's thesis conducted by the first author.

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