Increasing the Efficiency of Geothermal Energy Use through the Application of Piezoelectric Materials

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***Abstract*— The use of geothermal energy is less common than other types of renewable energy. This is due to the limited distribution of geothermal energy in limited areas, the difficulty of its use, and the problems of converting it into electrical energy. The temperature of geothermal waters in the Republic of Azerbaijan is below 100^0C, which makes their use even more difficult. The biggest difficulty is the extraction of geothermal water from the depths of the earth to the surface. The presented article proposes the use of electrical energy generated in piezoelectric materials to extract geothermal water to the surface. As we know, electrical energy is generated as a result of mechanical action in piezoelectric materials, and it is proposed to use this energy for the circulation of geothermal waters.**

Keywords—piezoelectric materials, geothermal energy, sensor, element, geothermal waters, clean energy

Introduction

In order to use geothermal waters emerging from the earth as renewable energy sources, it is first important to study the properties of these waters. Conducting chemical analysis of waters and studying the geological structure of the areas where these waters emerge is one of the main criteria. Also, determining the thermal-physical properties of geothermal waters and their comparative analysis with thermal waters emerging from other areas is important. Scientists from developed countries have carried out significant scientific research in this area.

I. Properties of Geothermal Energy Sources

The number of geothermal energy sources in our country is more than 200. The total amount of these sources per day is more than 100 million liters. These sources differ from each other in terms of mineral composition and temperature. Some of them are even used as drinking spring water. Significant scientific research has been conducted in this field for many years, and the sources, chemical composition, and other aspects of geothermal waters in the areas have been studied to a significant extent. Research into the thermal and physical properties of geothermal waters continues to this day.

The favorable use of geothermal heat has expanded its application in many countries in industry, agriculture, household and communal sectors, and medicine. One of the advantages of geothermal energy is that it does not require large financial resources for energy production and consumption.

There are thermal water sources in various areas of the Republic of Azerbaijan. There are enough geothermal water sources in the Greater and Lesser Caucasus Mountains, on the Absheron Peninsula, in the Talysh mountain-slope zone, in the Kura Depression and in the Caspian-Guba region. Thermal water in these areas can be used to produce heat and electricity.

Research is being conducted in developed countries to stimulate the use of renewable energy sources. The fact that thermal waters are accumulators of underground thermal energy and have high energy density indicates that they have special importance among renewable energy sources.

There are more than 1,000 thermal water sources in the Republic of Azerbaijan. 90% of them are in mountainous areas, and 10% are in plain areas. These thermal waters differ significantly from each other in their physical, chemical, and therapeutic properties. They contain methane, carbon dioxide, sulfur, nitrogen, and a small part contains radon. Thermal waters are dominated by carbon dioxide in the Lesser Caucasus, hydrogen sulfide and nitrogen in the Greater Caucasus, nitrogen-methane, hydrogen sulfide in the Talysh Mountains and nearby areas, and hydrogen sulfide and methane in the Absheron and Aran economic regions. The composition of thermal waters in Azerbaijan is dominated by carbon dioxide, hydrogen sulfide, arsenic, iron, bromine, iodine ions, organic substances, silicic acid, etc.

There are more than 60 thermal water sources in the liberated Kalbajar and Lachin regions of Azerbaijan, located in high mountainous areas 40 km from the banks of the Tartar River, such as Yukhari and Ashagi Istisu, Goturlu, Turshsu, Charakter, Bagirsag, etc. The composition of Bagirsag thermal water is very rich in radioactive elements. Thus, the amount of radium in these waters ranges from 1-10 curie/l to 10-11 curie/l. In general, thermal waters in the Lachin and Kalbajar regions are located 50-100 meters below the surface of the earth, with a temperature of 64°-80°C, and at the surface the temperature is 54.5°C.

In most regions of Azerbaijan, the temperature of thermal waters that naturally emerge to the surface reaches 60°C. The temperature of waters extracted from deep layers of the earth reaches +95°C. Thermal waters with relatively high temperatures are 85°C in Carlı, 64°C in Gotursu, 64°C in Donuzutend, and 62°C in Istisu. There are also thermal waters in Khaltan in Shabran district and Ibris in Gakh district.

In the mountainous zone of Masalli district in the Republic of Azerbaijan, the Arkivan thermal springs are high-temperature along the Vilash River, with a total flow rate of 5 1/sec and a mineralization rate of 15-16 g/1. The chemical composition of these geothermal waters is sodium-calcium chlorides, and methane gas is observed in the water. As a result of research, it was determined that the water temperature in wells drilled at a depth of 500 meters in the Arkivan mineral springs is $32\text{-}45^{0}$ C, the flow rate is 3-12 1/sec, and the chemical composition is sodium-calcium chlorides. The Meshasu and Ibadisu springs located in the Lankaran region have a flow rate of 25 1/sec, a temperature of 34-41°C, a mineralization degree of 3.5-6.0 g/1, and a chemical composition of sodium-calcium chlorides. There are up to 160 thermal and mineral water sources in the Talysh zone, including in the Astara, Lankaran, and Masalli regions.

Located at the foot of Mount Babazanen in the Salyan region, the Babazanen mineral waters contain hydrosulfide, methane, and calcium. Although there are numerous thermal waters in the plain regions of Azerbaijan, they are almost never used. As we know, the geothermal stage varies depending on the area. For example, there are geothermal sources in Agjabadi district with a temperature of 67°C emerging from a depth of 2000 meters, in Beylagan with a temperature of 75°C emerging from a depth of 2100 meters, and in Dalimamadli with a temperature of 83°C emerging from a depth of 1430 meters. Thermal waters that are not yet used in the mentioned regions are pressurized, and their flow rates in wells that spontaneously emerge to the surface of the earth are 10-12 1/sec. The chemical composition of the waters is mainly sodium chloride, and the degree of mineralization is 13 g/l.

The composition of geothermal waters in Azerbaijan varies depending on the area, thermal waters rich in methane gas are found in the vicinity of Baku, Babazanand, and the Talish zone. These waters are mainly used in recreation and treatment centers.

In Azerbaijan, geological exploration works were carried out in the Talysh zone (Astara, Lankaran and Masalli regions) in 1964-1970 for the purpose of studying thermal waters. The number of wells was 17, and the temperature of the geothermal waters in the wells was 38-64°C. These wells are still used as thermal energy. They are mainly used in the cultivation of cold-weather vegetables (tomatoes, cucumbers) in the winter months. This also creates conditions for harvesting 2-3 times a year. Geothermal waters with a total flow rate of more than 30,000 m3/day and a temperature of 50-81°C at the surface of the earth were identified through exploration wells in the Khudat-Khachmaz zone. It was confirmed that the reserves of these waters in the Khudat-Khachmaz zone are 25.7 thousand m3/day.

Many countries of the world, including Iceland, New Zealand, Italy, the USA, China, Japan, etc. geothermal waters and geysers are used for obtaining very cheap, ecologically clean electricity, heating buildings, greenhouses, various industries, restoring people's health, etc. purposes. The existing thermal waters in Azerbaijan are not used at the proper level. The forecast exploitation reserves of the existing thermal waters are 170,000 m3/day in the Kura depression, 21,000 m3/day in the Guba-Khachmaz region, 20,000 m3/day on the Absheron peninsula, 22,000-23,000 m3/day in the Talish highlands and Lankaran plain, 4,000-5,000 m3/day in the mountainous areas of the Lesser Caucasus, 3,000 m3/day in the Nakhchivan Autonomous Republic, and 2,000 m3/day on the southern slope of the Greater Caucasus, making a total of 249,000 m3/day or 249 thousand tons in the Republic. The mentioned potential is a small part of the reserves of geothermal waters. As can be seen, there is a sufficient geothermal energy source in our country to be used.

II. AREAS OF APPLICATION OF PIEZOELECTRIC MATERIALS

Piezoelectric materials are crystalline substances with well-defined piezoelectric properties used for the production of electromechanical transducers. They are used in the production of electrical energy, in the production of devices such as piezoelectric resonators, piezoelectric sensors, sound emitters and receivers. The main properties of piezoelectric materials are the electromechanical coupling coefficient, piezoelectric modulus, elastic modulus, conductivity. Also, requirements are imposed on piezoelectric materials such as high mechanical and electrical strength, weak temperature dependence of properties, high quality factor, moisture resistance.

Piezoelectric materials can be in the form of natural minerals or artificially grown single crystals (quartz, potassium and ammonium dihydrogen phosphates, Rochelle salt, lithium niobate, silicon selenite and germanoselenite, etc.) and polycrystals. Ferroelectric solid solutions (piezoceramics) that are subjected to synthesis polarization in an electric field belong to them. Only some crystals from the first group of piezoelectric materials are used, for example, quartz, which has the properties of high temperature stability, mechanical strength, low dielectric losses and moisture resistance. Their disadvantages are a relatively weak piezoelectric effect, small crystal size and difficulty in processing. They are mainly used in piezoelectric filters and frequency stabilizers. Quartz emitters and ultrasonic receivers are used in laboratory equipment. Ammonium dihydrogen phosphate is an artificially grown ferroelectric crystal, chemically stable, has a relatively strong piezoelectric effect and has a low density up to the melting point (130 °C), but is not mechanically strong enough. Rochelle salt crystals (growing to large sizes) have high properties that determine the sensitivity of the sound receiver. Low moisture resistance, low mechanical strength, as well as a strong dependence of properties on temperature (due to the low Curie temperature of 55 °C) and electric field strength limit the use of Rochelle salt. Lithium niobate, silicon selenite and germanoselenite, along with a strongly pronounced piezoelectric effect and high mechanical strength, have a high acoustic quality factor and are used in the hypersonic frequency range. Tourmaline, potassium hydrogen phosphate, lithium sulfate, etc. are practically not used. The most common piezoelectric materials in industry are piezoelectric ceramics.

Organic piezoelectric materials are also used. Polyvinylidene fluoride (PVDF) (thin film) and other organic piezoelectric (film) materials represented by it are also known as piezoelectric polymers. Such materials have high elasticity, low density and high DC voltage. They are widely used in underwater acoustic ultrasound measurement, pressure measurement devices, and ignition starters worldwide. The disadvantage is that the piezoelectric voltage constant is low, which limits its use as an active radiation transducer.

Organic composite piezoelectric materials are used in the manufacture of sheets, rods, and poles. These materials are also used in powder form. They have been widely used in underwater acoustics, electroacoustics, ultrasound, medicine, and other fields.

III. USE OF PIEZOELECTRIC COMPONENTS IN GEOTHERMAL ENERGY SOURCES

The use of geothermal energy is less common than other types of renewable energy. This is due to the limited distribution of geothermal energy in limited areas, the difficulty of its use, and the problems of converting it into electrical energy. The temperature of geothermal waters in the Republic of Azerbaijan is below 100^0C, which makes their use even more difficult. The biggest difficulty is the extraction of geothermal water from the depths of the earth to the surface. The presented article proposes the use of piezoelectric materials to extract geothermal water to the surface of the earth. As we know, electrical energy is generated as a result of mechanical action in piezoelectric materials. The generation of electrical energy is proposed in the following form (Fig. 1).

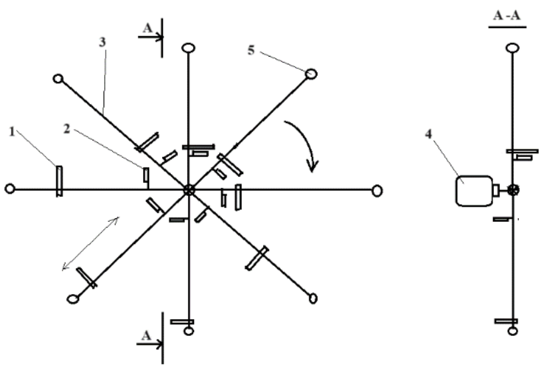

Fig. 1. The design of the device for influencing piezoelectric materials. 1-moving part for impact; 2-piezoelectric material; 3-support; 4-engine for rotating the system in which the supports are connected; 5-limiter.

Piezoelectric materials are used in devices, roads, household, cars, UAVs and other fields. In UAVs and electric cars, piezoelectric materials are used to charge their batteries.

As shown in Figure 1, when the moving part 1 strikes the piezoelectric material 2, an electric current is generated, this electric current is supplied to the engine, which in turn transmits rotational motion to the supports 4. Each time the part moving along the supports strikes the piezoelectric materials, an electric current is generated, and this electric current also moves the supports.

As we know, the circulation of geothermal waters requires little power. Piezoelectric materials rotate the support system and at the same time ensure the circulation of geothermal waters.

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