Piroelektrik malzemelerde döngü sayısı ile x ışını enerji seviyesi arasındaki ilişkinin doğrusal regresyon analizi ile belirlenmesi
Determining the relation between the count number and x-ray energy level in pyroelectric materials using linear regression analysis

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***Özetçe*—X ışınları, farklı alanlarda yaygın olarak kullanılan bir tür elektromanyetik enerjidir. Keşiflerinden bu yana, özellikle tıbbi görüntüleme uygulamaları için sıklıkla kullanılmışlardır. Bununla birlikte, daha verimli yeni x ışını üretim yöntemleri hala araştırılmaktadır. Her ne kadar yeni görüntüleme yöntemleri ortaya çıksa da, bilgisayarlı tomografi ve dental görüntüleme gibi çoğu uygulamada popülerliğini hiç kaybetmemişlerdir. Bu yeni yöntemler arasında, piroelektrik kristal malzemeleri kullanılarak x ışını üretimi umut vaad eden teknolojilerden birisidir. Pyroelektrik kristaller sıcaklık değişikliği meydana geldiğinde elektrik alanı oluştururlar ve bir kristalin sıcaklığının kaç kez değiştiği gibi farklı parametrelerden etkilenirler. Bu çalışmada, piroelektrik malzemelerdeki döngü sayısı ile x-ışını enerji seviyesi arasındaki ilişki doğrusal regresyon analizi ile araştırılmıştır. Bu amaçla, ticari bir yazılım paketi olan Sosyal Bilimler için İstatistik Paketi (SPSS) kullanılmıştır. Sonuç olarak, $R^2 = 0,91$ uygunluk değerine ulaşılmıştır.**

***Anahtar Kelimeler*—Piroelektrik; X-ışını; Doğrusal Regresyon.**

***Abstract*—X-rays are a type of electromagnetic energy which widely used in different areas. Since their discovery, x-rays used, especially for medical imaging applications. On the other hand, new efficient x-ray generation methods have still been under investigation. Although new imaging modalities arose, x-rays have never lost their popularity in many applications like computed tomography and dental imaging. Among these new methods, x-ray generation using pyroelectric crystal materials is one of the promising technologies. Pyroelectric crystals generate an electric field when a temperature change occurs and are affected by various parameters like how many times (count) the crystal's temperature changed in a second. Hence, this new technology needs more research. In this study, we investigated the relationship between the count number and x-rays' energy level of pyroelectric materials using linear regression analysis. We used a commercial software package, which is called the Statistical Package for the Social Sciences (SPSS), for this purpose. As a result, we achieved a good fit value of $R^2 = 0.91$.**

***Keywords*—Pyroelectric; X-ray; Linear Regression.**

I. INTRODUCTION

In 1895, Wilhelm Roentgen accidentally discovered a new type of rays and named them X-rays [1]. These rays can penetrate from matters with attenuation, which makes them suitable to visualize the internal structures; this property of X-rays used for medical imaging to monitor the inside of the body without any invasion. For medical imaging, X-ray beams are sent to the body and the attenuated beams are detected by films or digital detectors to obtain the image. At present other medical imaging techniques also utilize X-rays, like Computed Tomography and Fluoroscopy.

X-rays are one form of electromagnetic radiation and have ionizing effects. The wavelength of X-rays is between 0.01 nanometer (nm) and 10 nm. Electrons in a vacuum environment accelerated with high voltages, these electrons directed to a target material, interaction of the electrons and target material results in X-ray. Advances in technology also affected the X-ray generation methods. In 1992, Brownridge published a study for a novel approach for X-ray generation. In his work, pyroelectric crystals are used for X-ray production [2].

Pyroelectricity is the material's ability to generate an electric field when it is cooled or heated [3]. The polarization of the crystal depends on temperature change and the pyroelectric coefficient of the crystal. For X-ray generation, the pyroelectric crystal is heated and cooled in cycles and an electric field is created, this field is used to accelerate electrons and different materials used as target materials. Frequently used pyroelectric materials for this purpose are lithium tantalate and lithium

niobate. When literature is examined, studies with these crystals in varying conditions are available [4]–[7]. Although, the behavior of the pyroelectric crystals to X-ray generation is not fully understood. In this study, the relationship between count number and x-ray energy tried to reveal by using the linear regression method.

II. MATERIALS AND METHODS

A. Data

For this study, five distinct graphs of four studies were used to identify X-ray energy and count number relationship. In three of these studies, lithium tantalate (LiTaO3) crystal was used; the other study used lithium niobate (LiNbO3) [6], [8]–[10].

B. Methods

Regression analysis is a commonly used statistical method to investigate the relationship between variables. There are different types of regression methods in the literature, one of the most used and basic one is the linear regression analysis. The output of the linear regression model gives coefficients to obtain an equation [11]:

$$y = \alpha x + \beta \tag{1}$$

where y is the dependent variable, x is the independent variable, α and β are coefficients of the equation.

In this study, the effect of count numbers (x) on the X-ray energy level (y) was examined using univariable linear regression analysis. Outputs of the linear regression model give details about how efficient the model is. The p-value, which shows the statistical significance, is used to determine whether there is a relationship between the variables. Having a p-value smaller than 0.05 means that there is a statistically significant relationship between these variables. In addition, the R^2-value is the correlation coefficient having values from 0 to 1, which provides the goodness of a linear regression model [12]. The higher R^2-value means a better fit for the model.

To perform regression, Statistical Package for the Social Sciences (SPSS) software was used. SPSS is a software package that offers statistical analysis, machine learning algorithms, text analysis, open-source extensibility [13]. This software provides acceptable results in the literature.

III. RESULTS

The linear regression model between the count and X-ray energy values was obtained from five different studies from the literature. Thirty data points, at least, from these studies were included in this study. Table I shows the summary of the model, produced in SPSS. This summary covers the R-value, R^2-value, and p-value (significance, Sig.). Since p values are less than 0.05, corresponding studies of 1, 3, and 4 show statistically meaningful regression lines.

	Material	R	R^2	Sig. (p)
Study 1 [9]	LiTaO3	.96	.91	.00
Study 2 [9]	LiTaO3	.31	.01	.11
Study 3 [10]	LiTaO3	.83	.69	.00
Study 4 [6]	LiTaO3	.92	.85	.00
Study 5 [8]	LiNbO3	.12	.01	.70

Table I: Statistical analysis results for linear regression models obtained from five distinct studies in the literature.

The achieved equations from the regression analysis are

$$Energy_1 = -0.02 \cdot Count + 233 \tag{2}$$
$$Energy_2 = 0.62 \cdot Count + 83.72 \tag{3}$$
$$Energy_3 = -2.34 \cdot 10^{-3} \cdot Count + 22.99 \tag{4}$$
$$Energy_4 = -0.02 \cdot Count + 193 \tag{5}$$
$$Energy_5 = -0.04 \cdot Count + 34.69 \tag{6}$$

Since the studies of 2 and 5 don't show statistically meaningful results, equations 3 and 6 are not well-fitted equations.

Figure 1 shows a fit graph to visualize the efficiency of the obtained models using SPSS.

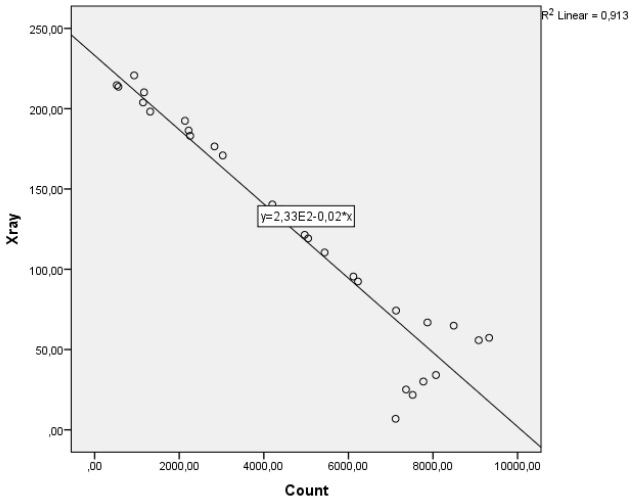

Figure 1: Fit graph of the example study 1.

IV. DISCUSSION

In this study, the data were collected from studies with x-ray generation papers based on pyroelectric crystals. Five graphs (from four studies) were included to determine data point pairs of count numbers and x-ray energy level. These data pairs were investigated using linear regression analysis. Table I shows the goodness of fits for each study. Results indicated that studies of 1, 3, and 4 can be modelled by a linear equation well while studies of 2 and 5 cannot produce well-fitted linear equations.

Equations of 2, 4, and 5 can be used in simulations studies to develop new technologies in this area. R^2 values of these equations are .91, .69, and .85, respectively. These values indicated that these models highly fitted to their actual materials' characteristics.

ACKNOWLEDGMENT

This study is based on a part of S.S. Egeli's M.Sc. study, and Y. Isler is the thesis advisor.

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