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Editor in Chief
Dr. Selahaddin Orhan AKANSU

HYDROGEN ROMANTIC

by Anna Green

About the Book

The idea of the Hydrogen Romantic book came to my mind after working for several years with the leading hydrogen energy scientists and observing their activities. One of those scientists, Dr. Turhan Nejat Veziroglu, has devoted his life to this topic, becoming much loved and respected around the world. In addition to all the momentous events in which Dr. Veziroglu has been involved, his memories are very interesting. Such a life is almost like navigating the pages of history, allowing admirers to gain information without being bored. I asked him to spend one hour with me every day, so I could interview him. During those one-hour periods, I asked him questions, and I recorded his responses. After I finished the interviews, I listened to the recordings. From this, I wrote the book. In addition, I did research on the sections dealing with the historical events. I've added this research as narratives in the book.

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PREFACE

Dear readers, researchers, scientists and industrialists,

The developments about energy and environment are changing rapidly in the whole world. Each living thing needs energy to live. Environment which has a vital importance for life is affected in the result of energy usage. For the reason of not using the environment in the correct manner, our world has been exposed to global warming. The damage that is given to the environment must be in the minimum grade during producing and consuming the energy, which is an indispensable element of many areas such as life, comfortability, production, and so on…

Scientists and industrialists are making intense studies, research and developments, about clean, sustainable, renewable, portable, and different resources originated procurable energy applications. Beside these storage of the energy in appropriate conditions is needed in terms of sustainability.

In this scope, Erciyes Energy Association, targets to provide a different dimension to its studies by making scientific studies, gathering the researchers, who make studies about energy and environment subjects, together in the scientific activities that are organized via its structure, making research and development works in the areas in question by following the innovations with the technology, giving technical educations in terms of supporting the young scientists who wants to work in these subjects, and generating not only domestic but also international collaborations.

In accordance with these purposes in the international activity named as "International Conference on Energy, Environment and Storage of Energy (ICEESEN)", which is started to be arranged in 2020, the technological developments about energy and environment was discussed with many participants coming from many countries.

In order to share the qualified studies made in similar subjects together with the studies made in this activity, an international journal named as “Energy Environment & Storage (enenstrg)” was published in the beginning of year 2021.

“Energy Environment & Storage” has an editorial board in which international prestigious scientists takes place. The studies that are published in the scope of the journal are exposed to extensive assessment of specialized arbitrators.

We are happy to present the first issue of “Energy Environment & Storage” journal that is based on providing contributions to the science World, and we hope to meet in next issues.

Dr. S. Orhan AKANSU

AIM AND SCOPE

Energy, Environment and Storage papers consider the prospects of energy technologies, environment, materials, process control and industrial systems. The Energy, Environment and Storage will be published 3 times per year.

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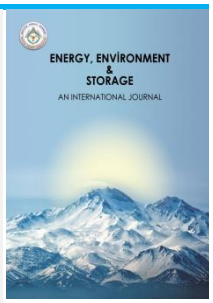

Evaluation of Environmental Noise Pollution (Traffic, Schools, Hospitals) and Noise Perception

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ABSTRACT. Nowadays, noise pollution, one of the crucial environmental problems as a result of increase in the population, has caused physical and psychological negativities in people's lives. The increase in the number of vehicles along with the population, the lack of infrastructure in the existing roads, misbehavior of the drivers due to the lack of education lead to an increase in noise pollution. The current study aimed to determine how much noise pollution that people are exposed to in traffic, schools and hospitals in Kayseri, one of the most important industrialized centers in Turkey with a population approximately 1.4 million. The levels of noise pollution averagely varied between 62-72 dBA in the streets and it is observed that the noise level changes depending on the vehicle intense in traffic. The noise levels in schools ranged from 41 to 57 dBA in the morning when window was closed that were higher than the regulation limit. The noise levels in hospitals were between 46 and 58 dBA when window is closed. The results of the survey conducted among a total of 153 people showed that noise was considered as environmental pollution by 98% in residential, 90% in schools and 73% in hospitals. The most noise-related health effects specified by the participants was the headache with 41% followed by frustrated and stressed with 24%.

Keywords:Noise pollution, traffic noise, noise perception, health effects.

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1. INTRODUCTION

Noise pollution is among the most important and almost certainly the most neglected environmental risks affecting health and comfort of people particularly in urban areas [1,2]. It was recognized as an important pollution factor for the first time at the United Nations Conference on the Human Environment held in Stockholm in 1972 [3,4]. World Health Organization pointed out “Noise must be recognized as a major threat to human wellbeing” [5]. By definition, noise is identified any unpleasant sounds that are disturbing or threatening health [6]. The major sources of noise are generally classified as traffic, railway, aircraft, wind turbine, leisure [5] and occupational [7]. Depending on duration and volume, the effects of noise on human health and comfort fall into four categories; physical effects (hearing disorders), physiological effects (increased blood pressure, irregularity of heart rhythms and ulcers), psychological effects (disorders, insomnia and late sleep, nervousness and stress) and inefficiency at work [8-10]. Besides adverse effects on human health, road-traffic noise induces depreciation of property and loss of rent, disturbance of wildlife [11]. Monetary equivalent of relatively severe noise pollution was estimated by Weinhold [12] at about €146 per month per household in 2003 prices and he/she stated it would be approximately €172 in 2011 prices.

Adverse effects of noise pollution on human health have been increasingly evident over the last couple decades [6,13,14]. According to the assessment threshold set out in the European Union Environmental Noise Directive, at least 100 million people in the European Union are affected by traffic noise and at least 1.6 million healthy years of life in Western Europe are lost as a result of traffic noise on the road. Therefore, the issue of noise among policymakers and the public remains an increasing concern [5]. Guideline Development Group strongly recommends reducing noise levels produced by road traffic below 53 dBA, produced by railway traffic below 54 dBA, produced by aircraft below 45 dBA, produced by wind turbines below 45 dBA and from all leisure noise sources combined to 70 dBA for average noise exposure [5].

Conversely, the increase in the number of vehicles, along with the population, the lack of infrastructure in the existing roads, and misbehavior of the drivers due to the lack of education has led to an increase in noise pollution.

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Especially after 1985 in Turkey the population and the number of vehicles has increased rapidly as a result of urbanization and industrialization [15]. Consequently, noise has become a serious environmental problem [16,17]. The environmental noise was regulated by "Regulation on the Evaluation and Management of Environmental Noise" on June 4, 2010 in the Official Gazette (no. 27601) in Turkey. Regarding to the Turkish regulation, there is a need to prepare strategic noise maps in areas where the population is more than one hundred thousand and the population density is more than 1000 per square kilometer [18]. According to the regulation on noise subjected by Ministry of Environment and Forest, the traffic noise level should be below 65 dBA (daytime) and 60 dBA (nighttime) in noise sensitive areas like education, health etc. Besides, the noise level was limited to 35 dBA and 45 dBA when windows were closed and open in interior of education facility and health facility areas, respectively.

Since it seriously affects human health, many studies have been carried out especially in metropolitan cities regarding the determination of environmental noise level and evaluation of its effects. Most of these studies are limited to either traffic, or hospital or school and some limited studies to evaluate environmental noise pollution in cities are available. Although 75% of the population in Europe live in urban areas [19], there are few studies available that have comprehensively evaluated the effects of noise pollution on people so far. The objective of this study was to determine the noise pollution caused by urban traffic, to evaluate traffic impacted noise pollution in sensitive areas like schools or hospitals and to reveal people perception towards to noise pollution. In the scope of the study, in order to determine the noise levels and its impacts on sensitive areas, 10 main boulevards, 9 schools and 7 hospitals were selected. The selected boulevards are the main arteries of the city of Kayseri, hospitals and schools are located on these boulevards. The survey was conducted with 153 people in the residential, school and hospital areas and 25 questions were asked to evaluate their perception on noise pollution. The people surveyed consisted of random people encountered on the boulevards, at the school and at the hospital during the measurement.

2. MATERIALS AND METHODS

2.1 Description of Study Area

Kayseri, one of the central areas of culture, art, science and tourism in Turkey, has maintained its importance in every period since history's ancient cradle of civilization. According to 2017 TURKSTAT data, the population of the province is about 1.4 million [15] and is located in southern part of Central Anatolia in Turkey. It has an area of 16.913,8203 km^2 and a traffic network length of about 2288 km. The city is expanding, and new streets are being built and added to the existing network. Noise pollution was studied in the city in 2017, during which sound levels were measured on 10 selected streets within residential-commercial zones, as these were thought to be the most representative of streets across the city.

2.2 Noise Measurements

The investigation and evaluation of environmental noise pollution was conducted in noise sensitive areas such as hospitals, schools and streets in the most densely populated areas of Kayseri (Turkey) during the period of spring season between April to June 2016. For the purpose of the study, 10 streets, 9 schools and 7 hospitals were selected in the most densely populated areas in the city. The list of measurement points and their locations are given in Table 1 and Fig 1. The noise levels were monitored between the hours of 08:00 and 09:30 in the morning and between the hours of 17:00 and 19:00 in the evening. The measurement time interval, commuting to work hours were chosen as the time when the traffic was the busiest and the noise level was the highest. During this study, street noise measurements were carried out in the city center of Kayseri on the streets and boulevards where the noise of motor vehicles was dense. On the streets and boulevards, the noise was measured at 3 points (the beginning, middle and end of the street) of each street for 3 weeks on Monday, Wednesday, Friday and Sunday. In hospitals and schools, relevant noise measurements were taken in the sections facing the street and settlement areas while the windows were open and closed. The outdoor measurements were carried out at an elevation of 1.5 meters from the floor and kept at least 2 m away from the walls and surrounding obstacles. The measurements at each point were repeated three times.

Table 1. The list of measurement points

Streets	Schools*	Hospitals*
Osman Kavuncu (St1)	Nursery School (Sc1)	H1
Kocasinan (St2)	Secondary School (Sc2)	H2
Sivas (St3)	Primary School (Sc3)	H3
Istasyon (St4)	High School (Sc4)	H4
Ahmet Pasa (St5)	Primary School (Sc5)	H5
Nato (St6)	Primary School (Sc6)	H6
Tuna (St7)	Technical High School (Sc7)	H7
Talas (St8)	High School (Sc8)	
Meliksah (St9)	High School (Sc9)	
Bilge Kagan (St10)		

*Due to the confidentiality of the data, the names of the schools and hospitals are hidden.

The noise measurements with the A-weighting scale (dBA) was determined using the Testo 816-1 Sound Level Meter. The Testo 816-1 allows measuring in the range of 30 to 130 dBA with two-time weightings, two frequency weightings, has minimum and maximum value functions, and allows individual value storage as well as measurement series storage. The device was calibrated in accordance with the operating manual before measuring the sound levels in selected points. A continuous sound measurement was recorded for 5-minute intervals and the sound levels considered were LAeq, Lmax and Lmin.

Noise levels monitored in the streets at three points were analyzed by kriging method, which is a spatial interpolation method, and noise distribution maps for Kayseri have been created. Spatial interpolation methods are frequently used to create spatial distribution maps from point data. Spatial interpolation is an estimate of the values of non-measured points by using the values of the sampled points.

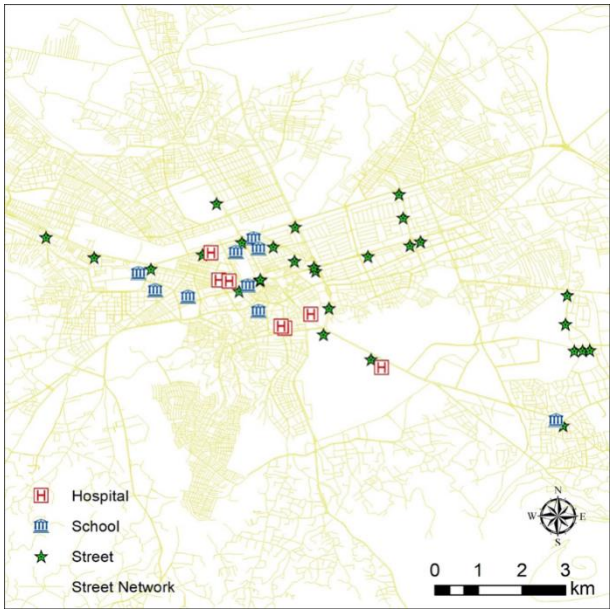

Figure 1. The location of measurement points.

2.3Survey Study

A survey was conducted at the hospitals, schools, and streets to evaluate the perception about noise. Survey questions were prepared to evaluate the perceptions that people have about noise pollution and socio-economic characteristics of individuals such as gender, age, occupation and education. A questionnaire consisting of 25 questions was conducted among randomly selected 153 people and face-to-face interviews were performed. The questions in the survey had multiple choice and the respondents could select more than one answer.

3.RESULTS AND DISCUSSION

3.1. Traffic Noise

Of all environmental related health problems, traffic-noise has been reported to be the most health-threatening stressors in Europe, with almost invariable affecting the entire urban populations at varying degrees [20]. In the current study, the average noise levels for ten streets in Kayseri are given in Figure 2 and the spatial distribution of noise levels are shown in Figure 3. On the weekdays, the noise levels on the streets varied between 62 dBA and 72 dBA in the morning hours and 62 dBA and 70 dBA in the evening hours. While the noise levels were higher during morning hours on Monday (Figure 2A), almost similar noise levels were measured on Wednesday (Figure 2B) and Friday (Figure 2C) during morning and evening hours. Overall, the noise levels during evening hours were higher than morning hours on Sunday (non-working day in Turkey). This is attributed to fact that people have the habit of resting at their homes and departing at different times at morning hours on Sunday. On the other hand, people end their social activities at similar times in the evening hours. The lowest noises were detected at Bilge Kagan Streets (St10) on weekdays and weekend. On weekdays, the noise levels were almost similar with around 70 dBA at all streets, except Meliksah (St9) and Bilge Kagan (St10) Streets. The streets on which the highest levels of traffic noise were recorded are characterized by heavy traffic as they are located in the densely populated and commercialized part of the city.

The statistical significance (ANOVA) of noise level at streets was evaluated based on weekdays and streets. The results of the ANOVA exhibited that there is no significant difference ($p>0.05$) between the average noise levels on the streets on morning and evening periods or in days when all street points are considered individually or together. In Turkey, traffic noise level should be below 65 dBA and 60 dBA during daytime and night time respectively in noise sensitive areas like education, health, etc. [17]. In all streets (except St10), the noise levels measured in the morning and evening are higher than the upper limit values specified by regulations either by local or international institutes, even on Sundays.

In a study of noise pollution evaluation in Abuja (Nigeria), day time mean noise level varied from 73.2 dBA to 83.6 dBA in 35 different points in the city [21]. That is much higher than the noise levels which were observed than this study. On the other hand, the noise levels at different streets in the city of Yazd (with a population of 430,000 in 2007) were reported between typically 70.9 dBA and 80.7 dBA [22]. Korfali and Massoud [23] observed noise levels greater than 70 dB in Lebanese urban areas and the highest noise level was reported as 79 dB. They attributed high measured noise levels to the high percentages of perceived traffic noise (88.5 and 90%) and motorcycles (82%). Birma et al. [24] evaluated noise pollution in Warri and Effurun Metropolitan Cities at 22 monitoring stations during the morning, afternoon, and evening periods and they did not observe significance difference within the different periods of the day at each sampling station. However, there is significant variation ($p<0.05$) in the mean noise values at each period of the day over all the sampling stations. The results of Seong et al. [25] on modeling road traffic noise in Fulton County revealed that the noise level of 55 dB(A) or higher affected 48% of the total county population during daytime. On the other hand, 32% of the population is exposed to noise levels greater than 50 dB(A) at night time.

Although traffic noise affects everyone living in the city, the most severe impact is seen in people who are closely involved in traffic such as drivers, passengers and pedestrians. Cai et al. [26] reported that higher levels of C-reactive protein, triglycerides, HDL cholesterol, and fasting glucose were significantly related with higher long-term traffic noise in densely populated areas. Sørensen et al. [27] stated that the risk of heart attack increased by 12 percent for every 10 decibels added to road traffic noise.

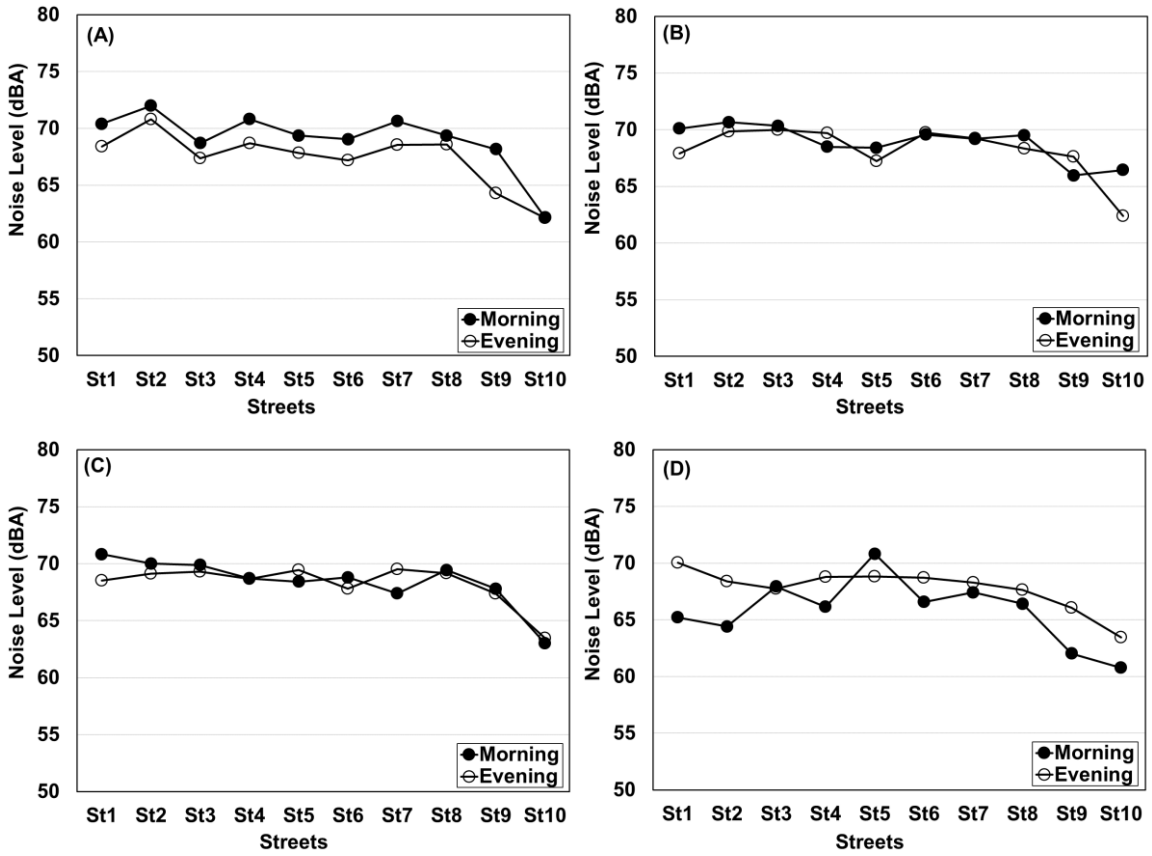

Figure 2. Average noise levels on the streets on Monday (A), Wednesday (B), Friday (C) and Sunday (D) in the morning hours of 08:00-09:30 and in the evening hours of 17:00-19:00.

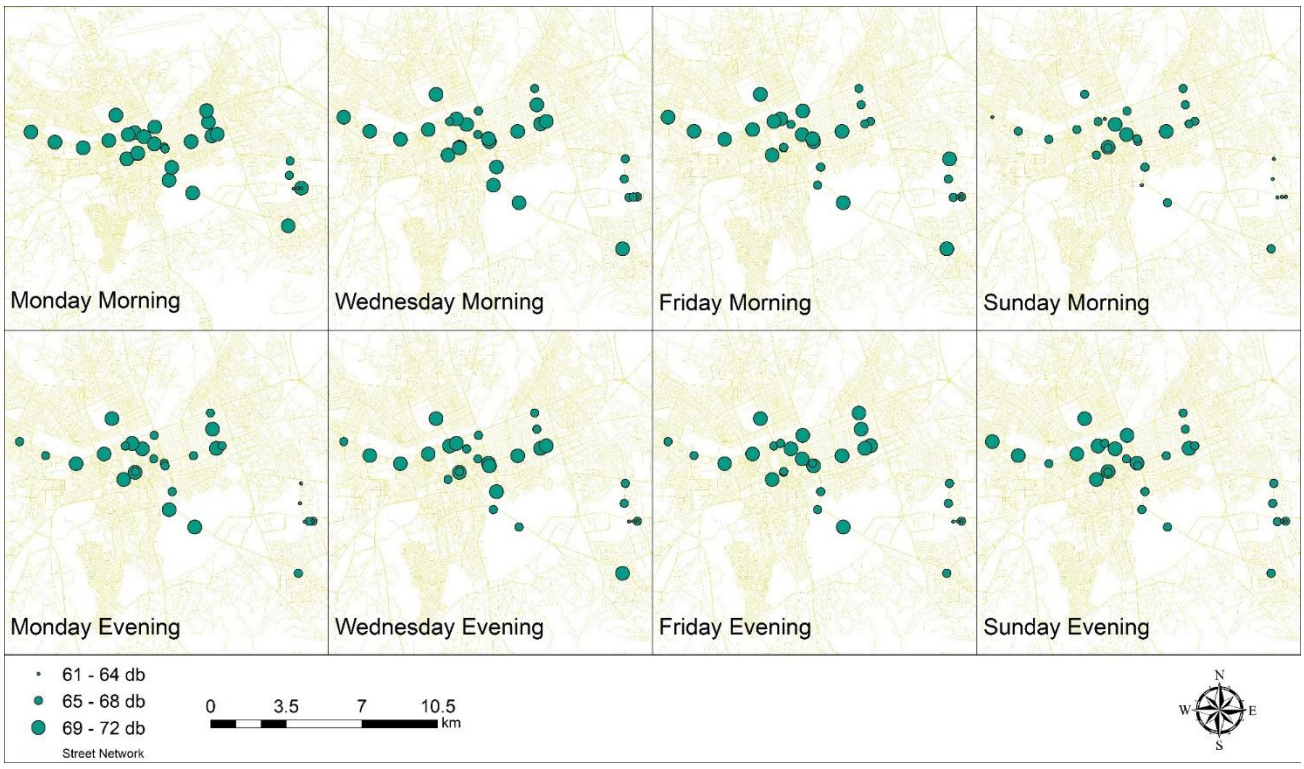

Figure 3. Spatial distribution of noise levels in the streets.

The studies reported prevalence of noise-induced hearing loss of 42.2% in the city of Curitiba, 55.5% (1998) and 46% (2000) in the city of São Paulo [28], 13% in Finland [29] and 21% in Mexico [30]. Hearing loss in drivers is important because of prolonged exposure to loud noise throughout the day, such that left ear shows more loss than right ear [31-33]. de Kluizenaar et al. [34] revealed that long-term exposures of noise lead to increased morning

tiredness on truck drivers. On the other hand, 10 years old children at home exposed to road traffic noise is much more inclined to behavioral problems and increased hyperactivity [35]. Noise pollution may lead to several personal disabilities, handicaps, and behavioral changes including fatigue, uncertainty, lack of self-confidence and concentration, irritation, misunderstandings, decreased working capacity, disturbed interpersonal relationships, and stress reactions. The effects of traffic noise on human behaviors can lead to increased accidents, impaired communication in the classroom and impaired academic performance [36].

3.2. Noise Pollution in the Schools

In the scope of the study, the indoor and outdoor noise levels were determined in 1 kindergarten, 4 primary and 4 high schools for a total of 9 schools. To assess the effect of outdoor noise, measurements were performed with closed and open windows in the closest classroom to the outdoor noise source. The observed average values are presented in Figure 4. The noise levels varied between 41 and 57 dBA in the morning when window was closed. The highest noise level was detected at Sc6 school, and the lowest noise was recorded at Sc3 school. On the other hand, the lowest noise was observed at Sc9 school with 39 dBA in the evening. Similar to the morning measurement, Sc3 school was the school where the highest noise level was observed in the evening. On the contrary, the other schools, the morning and evening noise levels did not change significantly, such as Sc5, Sc6, Sc7 and Sc8 schools. While the window was in the open position, the minimum and maximum noise levels were observed at Sc2 school with 52 dBA and Sc6 with 68 dBA in the morning (Figure 4B).

The outdoor noise measurements were almost similar with the values of window open position in the morning and varied between 52 and 68 dBA. However, the noise levels at outdoor locations were much higher than in the classroom when window open in the evening (Figure 4C). The highest noise was observed with 68 dBA at Sc6 school with either the window open or outdoors in the morning. The Sc4 school was among the schools was exposed to the highest outdoor noise with 71 dBA in the evening. According to the regulation on noise by Ministry of Environment and Forest, the noise levels inside classrooms were limited at 35 dBA and 45 dBA when with the windows closed and open, respectively. The noise measurements in all schools clearly showed that the noise levels were much higher than regulation limits with the windows in either the open or closed position.

Similarly, traffic-related noise problem (56-77 dBA) was reported in one school, which was located near highway in a study conducted in Malesia in three different schools. Teachers and students participated to the survey study pointed out disturbance of study/teaching (27%), hearing problem during classes (26%) and mental stress (17%) as the most common problem among the negative effects of traffic noise [37]. Forns et al. [38] indicated a positive association between noise exposure (38-51 dBA) at school and attention deficit/hyperactivity disorder symptomatology. Studies revealed that increased blood pressure [39] and annoyance reactions [40] were observed on children exposed to traffic related noise.

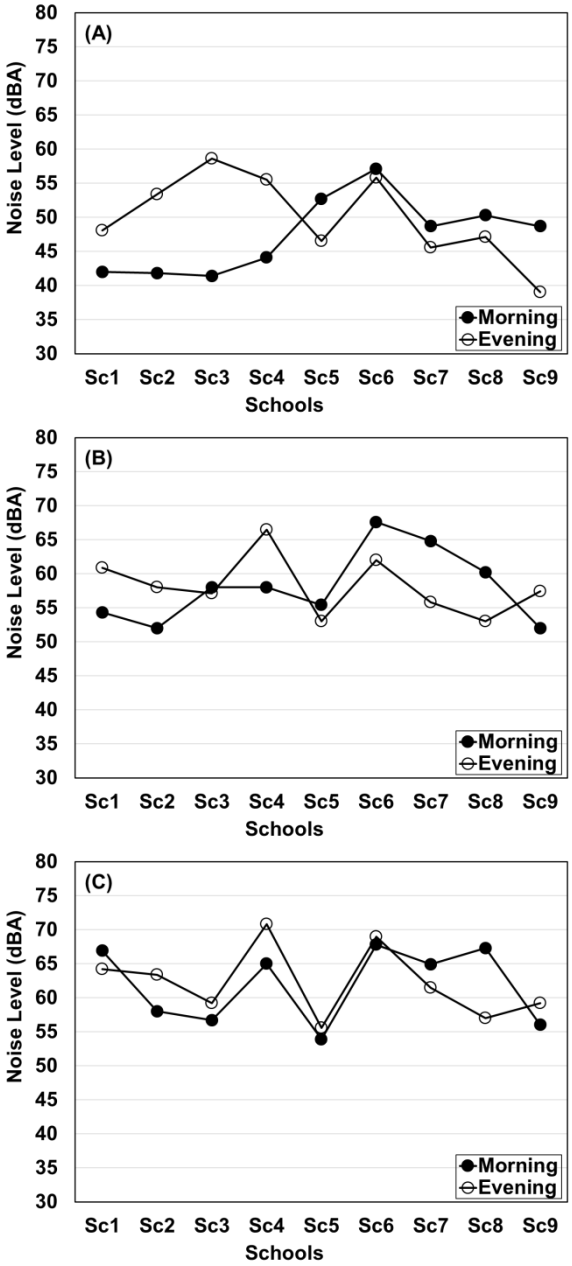

Figure 4. Average noise levels at schools: window closed-indoor (A), window open-indoor (B), outdoor (C) in the morning hours of 08:00-09:30 and in the evening hours of 17:00-19:00.

3.3. Noise Pollution in the Hospitals

Noise level was monitored in 7 private and governmental hospitals for three weeks and the noise level was measure three times at morning and evening between 08:00-09:30 and 17:00-19:00, respectively in different times with the window open and closed. In order to evaluate the long-term effects of noise on physiological and physiological health of patients and healing duration, noise measurements were performed in patient rooms. The observed results are presented in Figure 5. The noise levels varied between 46 and 58 dBA when window is closed (Figure 5A). The highest and the lowest noise levels were at H2 and H6hospitals. In fact, the noise levels

in all hospitals except H2 and H3 hospitals were varied in the narrow range of 55 and 58 dBA in the morning time. On the other hand, the noise levels in hospitals in the evening time when the window was closed were between 45 and 56 dBA, similar to the morning time. Although the noise levels at morning and evening times in the H1, H2 and H3 hospitals were almost the same, the noise levels at the evening time declined by 6 to 13 dBA similar to the morning values in other hospitals. Lower noise levels in hospitals at evening time was attributed to the quantity of patients. In particular, H1 hospital having the most capacity with 4 million patients annually, is always very crowded at day or night. Durduran et al. [41] reported higher noise levels in the morning than in the afternoon and evening.

Almost similar noise levels were observed when the window is opened in all hospitals and there is no significance difference ($p>0.05$) in noise levels between morning or evening measurements (Figure 5B). The noise levels ranged between 54 and 62 dBA in the morning and 56 and 62 dBA in the evening when window was open. Similar to noise measurements in the morning, the highest noise level was detected at H1 hospital. The noise levels were almost increased by 4 to 10 dBA when the window was opened. Higher noise levels were observed during evening measurements at H1 and H7 hospitals gardens, measured at 70 dBA and 58 dBA respectively. This might be attributed to the location of the hospital in the city, its distance to the street, the size of the hospital or immediate circumstances. All hospitals except H7 hospital are located in the center of Kayseri. H1 and H7 hospitals are on the main boulevards however the other hospitals are placed are more distant than the main roads. The noise measurements presented an exceptional example of H4 hospital that is near to one of the main roads in Kayseri, although the lowest noise was detected when window is open or in the garden (Figure 4C). The reasonable explanation for this example is that the hospital is placed in a planted garden and the hospital garden provides buffer zone for the noise pollution from the street. The values obtained in this context show that it is important to construct sensitive areas in quieter areas of the city. According to the regulation on noise by the Ministry of Environment and Forest, noise levels are limited at 35 dBA and 45 dBA when windows are closed and open in interior of health facility areas, respectively. According to measurements, the noise levels in all hospitals were exceeded the regulation limits for both the window closed and open situations. Grumet [42] reported that length of stay in hospital increased with higher noise levels and stated that noise control in hospitals should be considered as a priority issue. Allaouchiche et al. [43] monitored noise levels in postanaesthesia care units and reported that the mean, maximum and minimum noise levels as 67, 76 and 49 dBA, respectively.

In the study of Tsiou at. al. [44], noise level was evaluated in terms of Leq and its sources were identified during 43 surgeries in operating rooms. The result of the study revealed that the level of noise during the main procedure of an operation was Leq=71.9 dB(A) and machinery, tools, and conversation of people in the operating room were the noise sources. The noise levels at policlinics, clinics and other places (radiology, laboratories, and from corridors) during day-time in University Hospital in Samsun were 57 dB(A), 53 dB(A) and 61 dB(A), respectively [45].

Since hospitals are sensitive areas regarding noise pollution, health and comfort of both patients and staff are adversely affected by high level of noise. The studies revealed that the high noise increases the stress level of the hospital staff [46] and it can even cause mental collapse [47]. Pugh and Griffiths [48] reported that noise levels higher than 50 dB (A) caused sleep disorder in hospital patients. The research among nurses showed that long-term exposure to noise caused emotional exhaustion, depersonalization, and decreased personal accomplishment [47].

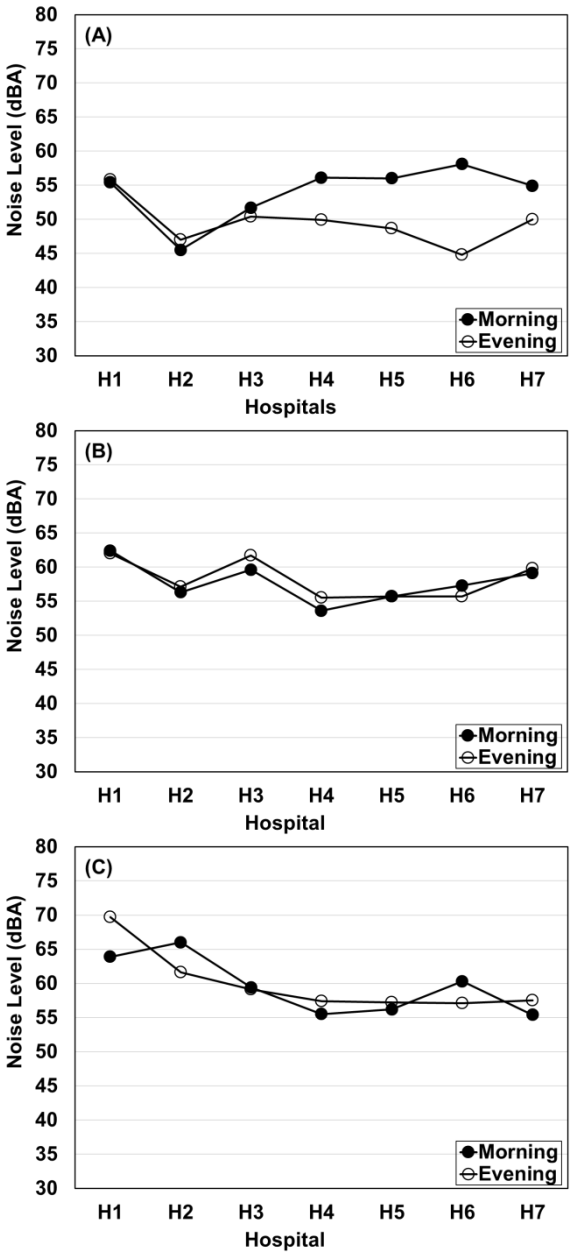

Figure 5. Average noise levels at hospitals: window closed-indoor (A), window open-indoor (B), outdoor (C)

in the morning hours of 08:00-09:30 and in the evening hours of 17:00-19:00.

3.4. Perception Survey for the Evaluation of Noise Pollution

The survey was performed among 153 people and the socioeconomic characteristics of the sampled population are presented in Table 2. Of the 153 people surveyed, 80 were female and 73 were male. The distribution of female is 25%, 39% and 36%, the distribution of males is 43%, 27% and 30% in residential areas, school and hospitals, respectively. 22 of the respondents stated that they had received elementary school, 16 secondary schools, 51 high schools, 13 high schools, 43 graduate and 9 graduate students. Although no educational privileges were considered during the survey, it was observed that those with low levels of education were worried about participating in the survey. The participants stated 23 are workers, 44 are civil servants, 38 are students, 21 are housewives and 23 are self-employed among the 153 participants.

According to the evaluation of survey data in residential, schools and hospitals, it was concluded that noise was considered as environmental pollution by 98% of the participants in residential, 90% in schools and 73% in hospitals. Noise sources were evaluated and the participants, 73% in residential, 68% in schools and 70% in hospital stated that the source of the noise was mostly found outside the house.

Table 2. Socioeconomics characteristics of individuals in the survey

Parameter		Residential	School	Hospital
Gender	Female	20	31	29
	Male	31	20	22
Education	Primary School	14	3	5
	Secondary School	11	2	3
	High School	14	10	27
	Collage	5	2	6
	Undergraduate	5	29	9
	Graduate	3	5	1
Occupation	Worker	7	5	11
	Officer	2	29	13
	Student	10	13	15
	Housewife	12	4	5
	Self-employment	21	-	2

The noise sources were classified as industry, transportation, unplanned urbanization, rapid population growth and human activities (street entertainment, construction works etc.) by the participants. 28% of the total number of participants indicated that the noise was caused by transportation vehicles and 21% was due to unplanned urbanization. It was reported that highways cause the most noise from the transportation group, which includes highway (69%), railway (21%) and airport (10%) categories. Automobiles (74%) and motorcycles (51%) have the most principal impacts on noise for transportation based on the received highest number of responses. When the participants were asked which place was most disturbed by the noise, the majority reported 36% home and the second most with 29% was traffic. The most disturbing time for noise for 50% of participants was during day-time between 07:00 and 19:00. For 48% of participants it was night-time between 19:00 and 23:00, and for the rest it was midnight.

In order to evaluate the effects of noise on health, the participants were asked which of the effects of noise they felt, such as frustration and stress, ineffectiveness in work, headache, and fatigue. The most prevalent impact of noise among the people in residential was headache with 41% followed by frustration and stress with 24%. On the other hand, 31% of the participants in the hospital suffered from headache, 33% of the participants in the school complained being frustrated and stressed. The ineffectiveness in work (14% in residential, 23% in school and 12% in hospital) was the third most common in all three groups following frustration, stress and headache. 12% of the participants reported that their relatives had noise related health problems. The participants were asked what kind of health problems affecting their relatives that had been caused by noise. Symptoms such as sleep disorder, stress related circulation disorder, mental problems, hearing impairment, social behavior disorders, motivation and communication disorders were among the effects caused by noise pollution. 85% of the participants responded with yes when asked whether tiredness caused by noise can cause accidents. Of the participants, 119 agreed that various noises affect the work to be done on time and accurately. A survey among 2391 people performed by Sundstrom et al. [49] showed that decreasing job satisfaction was significantly related with high level of noise. For half of the participants, preventing or reducing noise is considered as very important in terms of quality of life. 49% of the participants think that they have enough knowledge about the precautions to be taken to prevent noise. Among the main measures that can be taken for the prevention of noise are the prohibition of making noise, prohibition of causing high noise after certain hours, increasing inspections and the introduction of noise limit values.

The most important precaution taken to reduce the noise for the participants in residential (28%) and in school (33%) was the isolation of buildings and the prevention of traffic-related noise for the participants (35%) in hospital. 83% of the participants answered no for the question of "Do you think that efforts to stop noise pollution have been sufficient?" 91 out of 153 people reported to the authorities by phone call that they were disturbed by noise. However, 71 participants stated that their complaints about noise pollution were not resolved.

4. CONCLUSION

The noise levels monitored in the streets varied between 62 dBA and 72 dBA in the morning hours and 62 dBA and 70 dBA in the evening hours on weekdays. The noise levels in the streets located in the city center were much higher than located in suburban streets. There is no significance difference ($p>0.05$) in noise levels between morning and evening hours during weekdays. However, the noise levels on evening hours were, in general, higher than morning hours on Sunday. This fact is attributed to that people are generally resting at their homes and departing at different times in the morning hours of Sunday.

The noise levels in the schools were varied between 41 dBA and 57 dBA in the morning and between 39 dBA and 56 dBA in the evening when windows were closed. The noise was as high as 68 dBA when windows were open and 71 dBA in the outdoors regardless of whether it was morning or evening. The results obtained in schools showed that the noise level values recorded in the classrooms facing the settlement areas were lower than the measurements conducted in the classrooms facing the street side. The schools where low noise measurements recorded, generally, have buffer structures (e.g., planted garden or wall) that prevents the environmental noise such as traffic. The higher noise levels recorded in classrooms when windows were closed were the result of old building structure, the weakness of the insulation structures or distance from main boulevard.

The monitoring of noise in the hospitals showed that the noise levels were varied between 46 and 58 dBA in the morning and 45 and 56 dBA in the evening, when windows were closed. On the other hand, the noise levels were ranged between 54 and 62 dBA in the morning and 56 and 62 dBA in the evening when windows were open. The lowest noise level observation in H4 might be attributed to the hospital being placed in a planted garden and the hospital garden provides a buffer zone for the noise pollution from the street.

According to the responses by participants to the survey, 98% in schools, 90% in schools and 73% in hospitals say that noise is considered as environmental pollution. Among the 153 of participants, transportation and unplanned urbanization were indicated by 28% and 21% of the participants respectively as the major noise sources in the city. The most prevalent impact of noise among the participants was headache followed by frustration, stress and ineffectiveness in work.

Most of the participants agreed that noise has significant effects on timely and accurate work. According to half of the participants, reduction in noise pollution is crucial in terms of quality of life. Reduction in noise levels could be achieved by the prohibition of making noise, the prohibition of causing high noise after certain hours, isolation of the structures, increasing inspections and enforcement of existing law, and introduction of noise limit values.

In order to prevent noise pollution and decrease the level, as well as serious precautions should be taken, it is necessary to give importance to city planning, to insulate buildings, to increase the level of education and awareness of people. Sensitive areas such as the school and hospital to be established should be located after the noise analysis in the region. In addition, it should be planned to be well insulated to outdoor noise and away from the main streets with heavy traffic. Buffer areas (trees, green refuges, green fences, etc.) should be created on the roadsides in order to prevent traffic noise from reaching residential areas, schools and hospitals.Urbanization should be planned so that business and entertainment centers, education and health areas, which cause high noise and settlement, are separated from each other.

Disclosure of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Ethics approval and consent to participate

No ethical approval was required as the survey was optional and anonymous, and the aims of study explained to all candidates prior to performing the survey. The questionnaires compiled in this study were conducted with random volunteer participants over 18 years of age who were met in the street, hospital or school (teachers only) during noise measurements.

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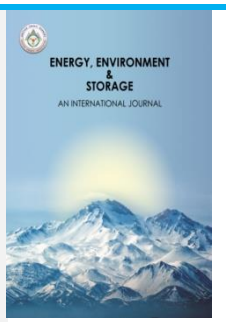

Investigation of the Solidity Ratio in a Horizontal Wind Turbine

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ABSTRACT: A wind turbine-generator system; Parameters such as wind speed, turbine blade diameter, number of blades, turbine height, tip speed ratio and solidity ratio are affected. In this study, horizontal axis wind turbine with diameter of 130 cm and blade solidity ratio values of 7%, 8,6% and 9,8% were constructed and the tests were made according to different blade speed ratios. The required blades were obtained from PVC pipes of different diameters. The experimental study was actualized in Erciyes University Mechanical Engineering, Engines Laboratory. For each profile, blade rotational speeds and wind speeds at various distances have been studied. It has been determined that the wind speed is reduced by the distance difference and accordingly the number of blade speed is decreased visibly. In the wing profiles with different blade solidity ratios resulting from the work done, the wing structure with the solidity ratio of 8.6% gave the best performance. C_L and C_D coefficients of the profiled specimens were analyzed by FLUENT^{TM}, a program of computational fluid dynamics. One of the factors that should be taken into consideration in the production of wind turbines is the blade solidity ratio.

Keywords: Solidity, Aerodynamics, Tip speed ratio, Wind turbine

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1. INTRODUCTION

In today's world where fossil fuels are being consumed rapidly, the use of renewable energy sources is of great importance in order to meet the energy needs of the world. The most important of these renewable energy sources are wind, waves, solar rays, hydraulics, biogas and geothermal. These are resources that are widely used and prone to development. Wind energy, one of the renewable energy sources, is one of the most promising sources for electricity generation.

China, the USA, Germany, Spain and India lead the way in electricity generated from wind energy in the world. The total wind energy installed power of these countries constitutes 72% of the world wind energy installed power [1,2]. Turkey ranks 7th in Europe and 13th in the world in terms of wind power plant installed capacity [3].

Turkey, which is surrounded by seas on three sides, has great wind energy potential, especially the Marmara coastline and the Aegean coastline. At the same time, stable wind quality rapidly increases the wind orientation in our country.

Different types of wind turbines are used to generate electricity from wind energy. Recently, modern horizontal axis wind turbines are more preferred for electricity generation. The lifespan of these types of wind turbines varies according to turbine quality and local climatic conditions.

In wind turbine design, the efficient operation of the system, in other words, the aerodynamic performance parameters have a great role. For this reason, scientists and researchers around the world have made a wide variety of studies on this subject. Yılmaz et al. [4] experimentally investigated the performances of different wing profiles in their study. As a result of the results they obtained, the angles of attack of different wing structures determined the CL/CD ratios.

In his study, Govind [5] tried to overcome the problem in the aerodynamic torque limit of horizontal axis wind turbines by adding a vertical axis rotor to the system. As a result of the research, he achieved an increase in efficiency in the system he designed as a hybrid.

Baloutaki [6] turbines systematically placed wind tunnels in different arrays and took measurements. They provided the most suitable conditions in triple arrays and determined that the distance between the two turbines should be one rotor diameter.

Oueslati et al. [7] carried out their experiments numerically by suddenly changing the blade pitch angle in

a horizontal axis wind turbine. As a result of their studies, they determined that sudden changes cause an increase in the resistance coefficient.

Specially designed standard blade sections consist of two curved surfaces. The lengths of the sections are called the blade section beam length (chord) and are denoted by *c*. The vertical length between the two surfaces is called the blade section thickness and is denoted by *t*. The front part of the section that meets the flow is called the leading edge, and the other part is called the trailing edge. The line connecting these two ends is called the blade section beam line (chord) [1,8].

Abdelsalam et al. [9] investigated two system design Horizontal axis wind turbine experimentally using open air jet test ring. The first of their proposal classical rotor and non-linear chord and twist. Another one is linearized rotor system. They implemented on diameter of 1 m rotor by changing free stream air velocity form 5 m/s to 10 m/s. Moreover, the pitch angles were changed. According to results the maximum Cp values are 0.446 and 0.426 for classical and linearized rotor design respectively.

Vaz and Wood [10] used a diffuser based on Blade Element Momentum (BEMT) theory in order to optimize. As a result of this procedure that concluded that the power output increased by 35%.

Duquette and Visser [11] examined blade number and the solidity effect on the performance of HAWT with different theories such as BEMT, rigid wake mothod (RWM) according to Kotb [12] and expanding wake model (EWM) based on Gould and fiddes [13].

Duquette et al. [14] studied an experimental investigation to examine solidity and number of blade on a 50 W HAWT in open circuit wind tunnel. The solidity was changed between 0.07-0.24 by altering number of blades. Similarly, Change in solidity, blade number and pitch angle were studied by Rector and Visser [15]. They used 3 and 6 blades for turbine rotors. Rsults indicated that the performance incresead by blade number and solidity at low flow regimes. On the other hand, 3 bladed rotor was more efficient that 6 bladed system.

Wang and Chen [16] investigated the effect of number of blade on the performance characteristics of ducted wind turbine using CFD with k-ε turbulence model with wall function. They stated that with the increase in the number of blades, starting torque increases and reduces the cut-in speed.

The fluid (air) coming to the blade section with free stream flow velocity, V creates a pressure difference between the lower and upper surfaces because of the specially designed geometry of this section. Due to this pressure difference, a dF_L lift force occurs perpendicular to the flow direction. The angle that the velocity, V makes with the blade chord line is called the angle of attack and is denoted α. Here, the symbol dF_L is used instead of F_L, since the lift force is written for the wing element with length dr. The unit of F_L is N (Newton), while the unit of dF_L is N/m (since it is the force acting per unit length). In the wing section, a second force occurs besides the lift force. This force occurring in the direction of flow is called drag force and is represented by dF_D.

C_L is the lift force coefficient, where V is the air velocity, dF_L lift force on the wing element and dF_D drag force:

$$C_L = \frac{dF_L}{\frac{1}{2}\,\rho\, V^2 c\, dr} \tag{1}$$

C_D, drag coefficient;

$$C_D = \frac{dF_D}{\frac{1}{2}\,\rho\, V^2 c\, dr} \tag{2}$$

In these equations, C_L and C_D coefficients are dimensionless.

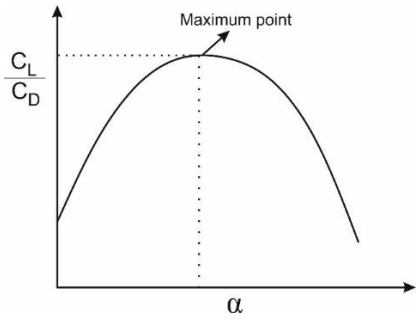

Figure 1. Design angle of attack point.

The angle with the highest lift/drag ratio is taken as the design angle for wind turbines. Figure 1 shows behavior of blade characteristics and at which angle of attack it gives the maximum C_L/C_D value.

The biggest disadvantage of wind turbines is that the constantly variable wind speed causes voltage and power (frequency) fluctuations on the load side. In this study, it was aimed to eliminate these negativities by determining the wing structure with optimum blade solidity. In order to determine that the wing solidity is at the optimum level, the wing tip velocity ratios of the profiles were used.

2. MATERIAL AND METHODS

In this section materials and methods were explained in two categories as experimental and numerical section.

2.1. Experimental Set-up

In order to determine and compare the blade solidity, while three different profiles were used the same sweeping area were determined in the experiment. These designed blades are made of PVC material and are cut from pipes with diameters of 70, 90 and 100 mm, respectively. The blade profiles with different radii of curvature were moved with the help of two fans rotating at 250 rpm, and the speed of the blades was determined with the help of digital tachometer (Figure 2).

Figure 2. Digital tachometer.

Figure 3. Anemometer.

Free stream wind speeds generated by the fans used to rotate the turbine blades were measured by anemometer as shown in Figure 3. Since it is connected to the propeller and the main body with a cable, it does not interfere with the flow area.

The solidity ratio was obtained by means of equation (3). After determining the resulting wind speeds, the blade tip speed ratios in each manufactured blade were calculated using equation (4).

$$Swept\ Area = \frac{\pi D^2}{4} \quad (3)$$

$$\sigma = \frac{Blade\ Swept\ Area}{Swept\ Area} x100 \quad (4)$$

$$\lambda = \frac{R\omega_t}{V_W} \quad (5)$$

Findings obtained from the above equations are given in Table 1 below.

Table 1. Data of the different models.

	Model-1	Model-2	Model-3
∅ (mm)	70	90	100
σ (%)	6,9	8,6	9,8

The real and schematic experimental setup is shown in Figure 4a and figure 4b. Also, details of the wind turbine were given in Figure 5. The wind speed was determined by moving the turbine closer to the fan (with a distance *L*). The values of the wings measured by means of anemometer and tachometer and the wing tip speed ratio values and blade revolution numbers calculated based on these are given in Figure 6 and Figure 7.

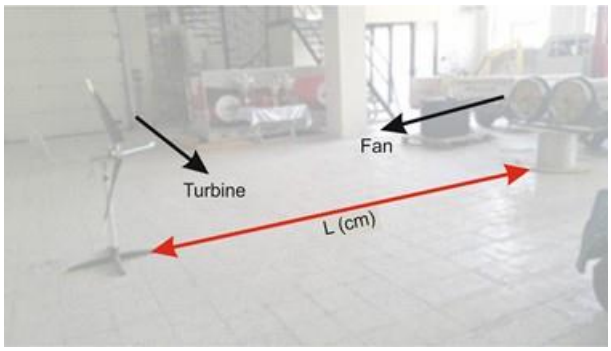

Figure 4a. Real demonstration of experimental set-up.

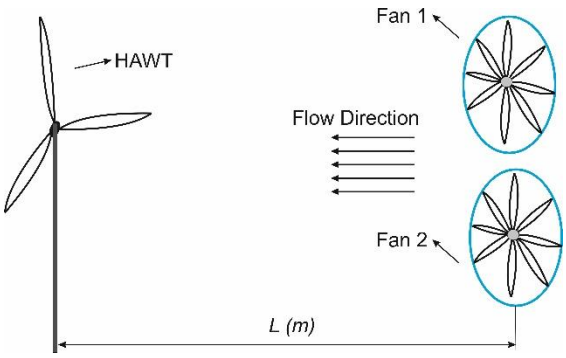

Figure 4b. Schematic representation of experimental set-up.

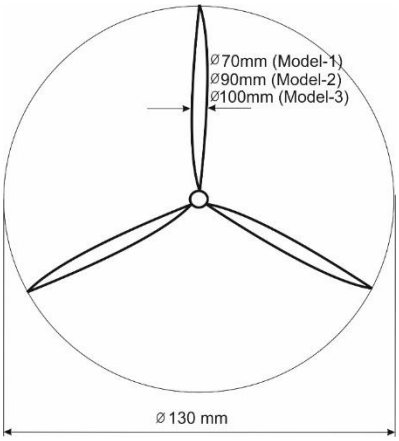

Figure 5. Detail presentation of wind turbine.

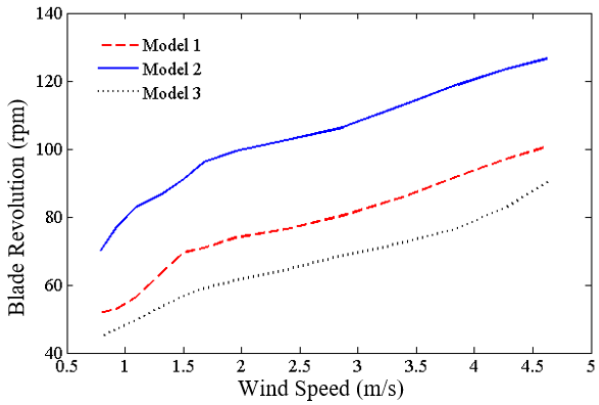

Figure 6. The number of revolutions of the manufactured turbine depending on the wind speed.

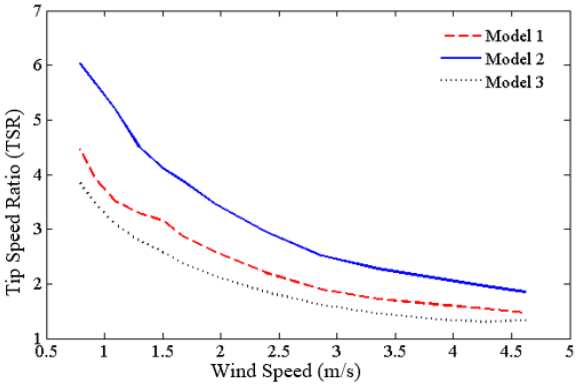

Figure 7. Blade tip speed ratio values depending on the wind speed of the turbine.

With the increase in wind speed, the number of revolutions of the turbine increases at every three solidity rate (Figure 6). The highest rotational numbers were obtained with 8.6% ratio. The blade tip speed ratio decreases with increasing wind speed (Figure 7). The blade tip speed ratio increases with the increase of the turbine speed and decreases with the increase of the wind speed. The increase in wind speed is more than the increase in the number of revolutions. Therefore, it was concluded that the profile with 8.6% solidity ratio is the most suitable.

2.2. Numerical Study

The C_L and C_D coefficients were determined by means of the FLUENT program, depending on the velocities of the designed and manufactured blades at the determined distances. In the analysis, "second order upwind discretization" solution was chosen in free environment and the equations were solved with "SIMPLE Coupled" solution algorithm. In addition, Spalart-Allmaras turbulence model was used in the analysis. In the modeling, the airfoils are placed inside the control volume, which is an infinitely large flow medium.

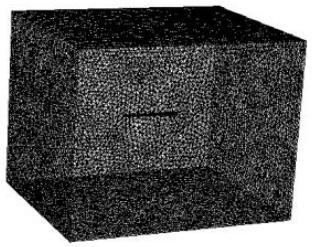

Figure 8. Mesh of the control volume.

Testing of the mesh independence is important to check the accuracy of the numerical results [17]. In this experiment, between 2-6 million meshes were used and obtained results showed that there was less difference by using the more grid. So, 2 million meshes were adjusted to investigation. Table 2 shows the approximately number of mesh tried in the numerical experiments.

Table 2. Number of mesh.

C_L	Number of Mesh
0,09	400000
0,15	600000
0,22	800000
0,35	1000000
0,55	2000000
0,552	3000000
0,557	4000000
0,558	5000000
0,559	6000000

The control volume is designed as a rectangle. The mesh of the that zone was demonstrated in Figure 8. For the calculation of the C_L and C_D coefficients, the convergence criteria were taken as 0.0001. The variation of C_L and C_L/C_D values obtained for three different profiles by means of FLUENT program depending on wind speed and Reynold numbers are given in Figures 9 and 10.

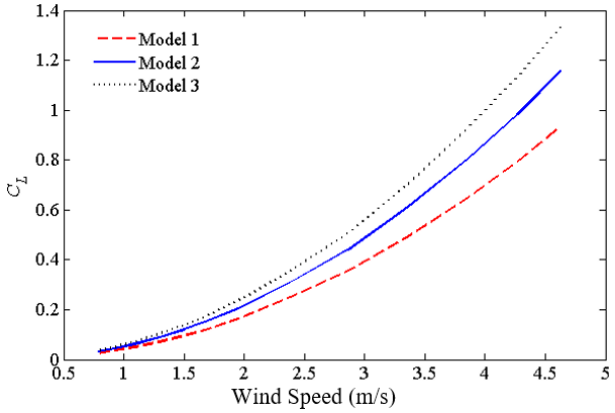

Figure 9. C_L values of turbine blades according to wind speed.

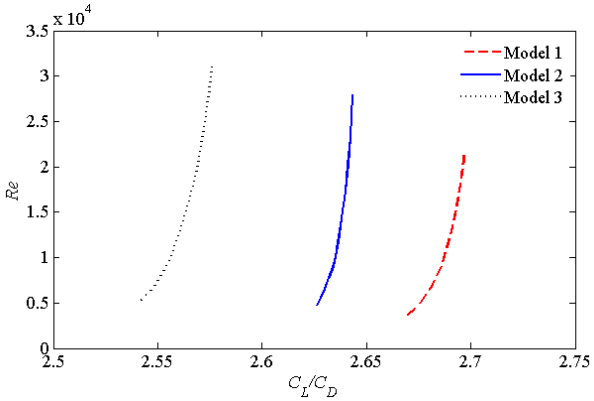

Figure 10. Changes in C_L/C_D versus Reynolds number.

The numerically calculated CL coefficient was the highest in model-3 (σ=9.8%). It is seen that as the solidity ratio increases, the lift force on the wing increases more than the drag force. However, the highest value of CL/CD was found in model-1 (σ= 6.9%). The drag coefficient increases as the solidity ratio increases.

While the pressure distributions occurring at the maximum wind speed on the wing are given in Figure 11, the velocity values of the airfoil are shown in Figure 12.

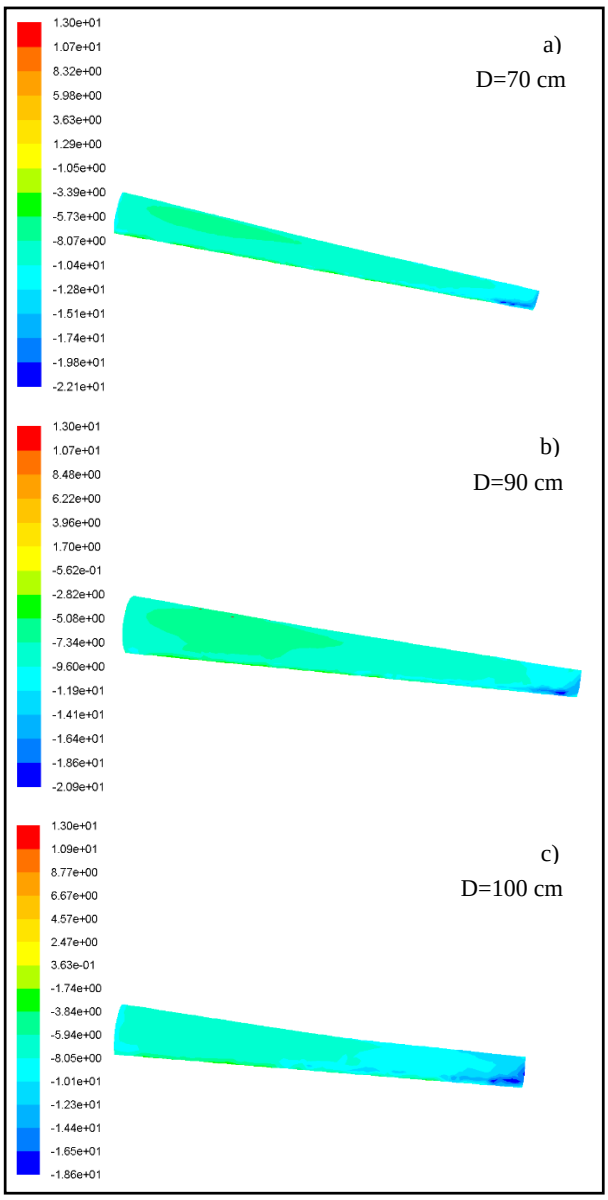

Figure 11. Pressure distribution of blade at 4.6 m/s wind speed, a) D=70 cm, b) 90 cm and c) 100 cm.

According to the results of the numerical analysis, although the free stream flow velocity remained constant, the high pressure zone formed at the top of the blades with 70 and 90 mm diameters decreased as the blade diameter increased to 100 mm, as can be seen in Figure 10 and Figure 11. Similarly, the increase in the blade diameter provided a decrease in the pressure values occurring at the ends.

The velocity vectors of the wind acting on the airfoil are shown in Figures 12. As same procedure applied the free flow velocity remains constant, the change in blade diameter affects the values exposed on the profile. In the profile above 90 mm, the velocity at the wing tip decreased, and then a slight increase was observed.

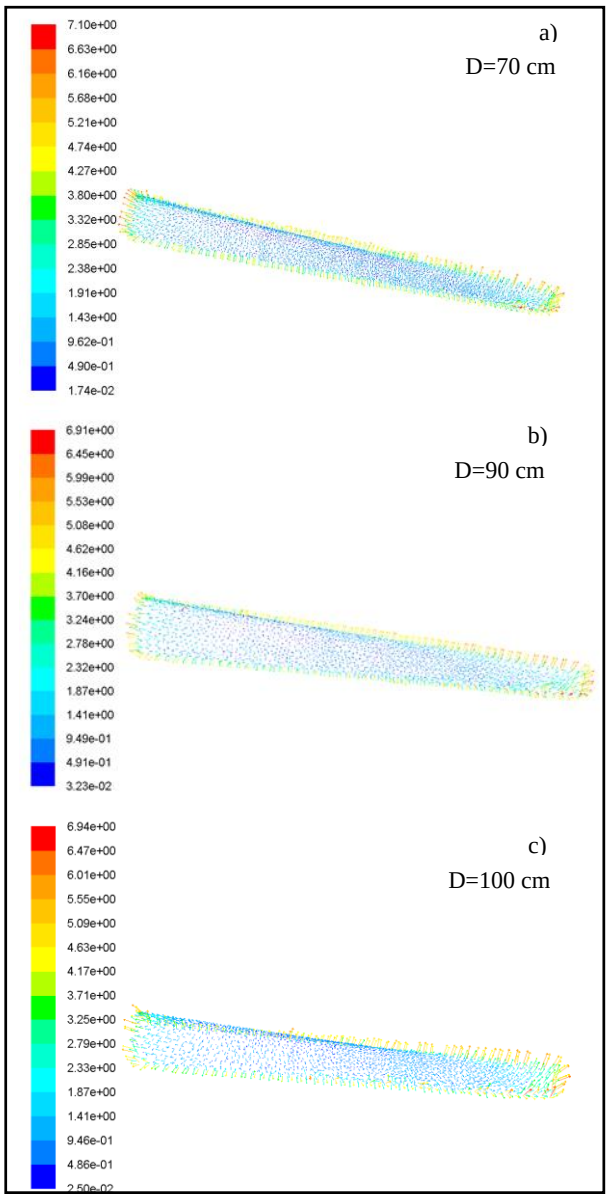

Figure 12. Velocity Vectors of blade at 4.6 m/s wind speed, a) D=70 cm, b) 90 cm and c) 100 cm.

3. RESULTS AND DISCUSSIONS

In this study, the effect of solidity ratio on horizontal axis wind turbine performance was investigated. The study was carried out at three different solidity ratios and the aerodynamic performance of each airfoil was examined numerically. Obtained results are shown below;

In numerical study;
- In model-3 (σ=9.8%) with the highest lift and drag coefficient surface area (solidity ratio);
- It was determined that the highest C_L/C_D value was in model-1 (σ=6.9%).

In the experimental study;
- The best performance was found in model-2 with the highest blade tip speed ratio (σ=8.6%).

In numerical calculations, the best airfoil seems to be model-3 according to C_L, and model-1 according to C_L/C_D ratio. However, in the experimental study, the best performance was obtained from model-2. Since Model-1

does not have sufficient surface area, Model-3 cannot give the entire wind force to the turbine due to its high frictional resistance and drag coefficient. Due to; In the manufacture and design of a turbine, along with the necessary numerical studies, experimental studies should be carried out to determine the optimum blade solidity value and production should be carried out accordingly.

Nomenclature

σ	Solidity Ratio [-]
D	Rotor diameter [m]
λ	Tip Speed Ratio [-]
R	Rotor Radius [m]
ω_t	Rotor Angular Velocity [rad/s]
V_W	Wind Speed [m/s]
Re	Reynold Number [$= \rho VL/\mu$]
ρ	Density [kg/m^3]
μ	Viscosity [kg/m s]
L	Characteristic Length [m]
C_L	Lift Coefficient [-]
C_D	Drag Coefficient [-]
c	Chord Length [m]

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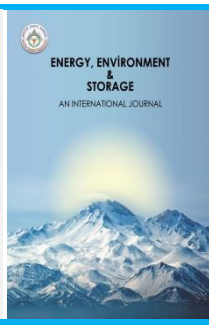

The Relationship Between CO_2 Emissions and Economic Growth in Turkey

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ABSTRACT. The relationship between environmental pollution and economic growth has recently been the focus of discussion between policy makers and scientists around the world. The relationship between environmental pollution and economic growth has recently been the focus of discussion between policy makers and scientists around the world. In order to meet human needs, energy is needed in the activities to be carried out and the demand for this energy has increased exponentially over the years. Today, energy is produced from two sources: fossil fuels and renewable resources. Turkey renewable energy resources, particularly hydropower, wind energy, solar energy and is a country with significant potential for geothermal energy sources. Compared to fossil fuels, the carbon emissions from renewable energy sources are low. CO_2 emissions from the use of fossil fuels vary depending on the type of fossil fuel used. In this study, the energy sector between Turkey's 1990-2016year, agricultural activities and carbon emissions per person from industrial processes and the per capita change in the manufacturing sector with the relationship between GDP energy imports, health care costs have been analysed.

Keywords:CO2 emission, GDP, Energy production

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1. INTRODUCTION

The industrial revolution is a major and radical change in the production structure and economy, thanks to the use of new power sources such as steam and mechanization. This development, which is also expressed as the industrial revolution, started in Europe in the second half of the 18th century [1]. With the development of the industrial revolution, fossil fuel consumption has increased rapidly. Today, developed countries have increased their fossil fuel consumption with the industrial revolution, and environmental pollution has begun to increase by accelerating the destruction of forests, agricultural lands and similar natural resources. Until today, urbanization and industrialization are increasing. In this case, the amount of greenhouse gases, especially CO_2, increases gradually.

Since the 19th century, the world's average air temperature has increased by 0.3 - 0.6 C°. It is estimated from researches that it will increase by 0.1 C° for every 10 years in the next 40 years [2].

Along with industrialization, the economic growth of countries has also increased. Gross Domestic Product (GDP) and Gross National Product (GNP) are the two main measures of economic growth [3]. In short, GDP (Gross Domestic National Product) is the sum of the monetary values of goods and services produced in a country in a year, in terms of current prices (market price). GNP (Gross National Product) is the sum of the monetary value of the final goods and services produced by a country's production factors in a year, in terms of current prices. GNP is obtained from the sum of GDP and foreign income [4].

There are many studies on environmental awareness, economic growth-income relationship and energy-related carbon emissions. The relationship between environmental pollution and per capita income is based on the Environmental Kuznets Curve (EKC) hypothesis. According to the Kuznets Curve shown in Figure 1., there is an inverted-U-shaped relationship between economic growth and income distribution inequality. In this theory, it is argued that income distribution will deteriorate first

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with economic growth and development, and income inequality will decrease as income increases continue [5].

Jalil and Mahmud analysed the relationship between carbon emissions, energy consumption, income and foreign trade for the 1975-2005 period for the Chinese economy. The result of the study confirms a relationship between carbon emissions and GDP per capita that supports second order EKC [6]. Artan et al. examined the relationship between environmental pollution and economic growth for Turkey data between 1981 and 2012. As a result of the findings obtained from the study, they determined a long-term relationship between economic growth and environmental pollution [7].

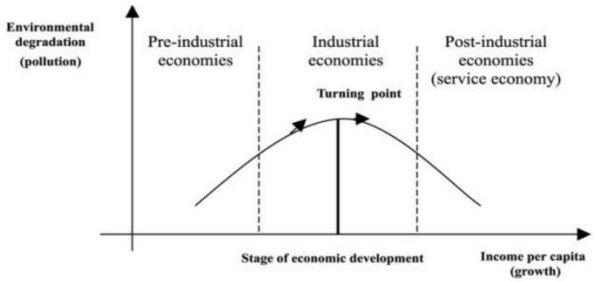

Figure 1. Environmental Kuznets Curve: Development Environment Relationship [8].

2. DEVELOPMENT AND COUNTRIES

The level of development in countries is mostly related to the economic structure of that country. Depending on the economic situation, social life and cultural structure are also among the criteria of development. Due to the differences in the economic, social and political structures of the countries, their development levels are also different from each other. Different criteria are used when determining the level of development of a country. The most important features of developed countries are that they use advanced technology and that a significant part of the employees work in the industry and service sector. According to these criteria, countries can be considered in two groups as developed and developing. The biggest criterion used to compare the development levels of countries is per capita income. Energy consumption is high in countries with developed industry and high living standards. Products exported abroad in developed countries are mostly industrial products. The raw material and food sector constitute the majority of the products imported into the country. The fact that the products sold bring high income to the country and the products purchased are low-priced products provide commercial income to the development. Developing countries buy high-income products and sell low-income products. For this reason, foreign trade deficits constantly occur. In such countries, the country's resources are not sufficient to utilize natural resources. Dependence on economically developed countries is high [9].

This industrialization, which has increased rapidly in the world, has led to global warming problems. Due to the increase in greenhouse gases sent to the air as a result of the use of fossil resources as fuel, gas rates per capita are gradually increasing. This increase can be seen to decline as some countries start using renewable energy sources. The use of renewable energy is increasing in most countries compared to the first years. In our study, the data of Germany, France, the Netherlands, Turkey, India and Brazil, which were examined between 1990 and 2016, were collected. Energy production and consumption, renewable energy production amounts, GDP and CO_2 emission data from development levels were examined separately for each country [10].

2.1 Energy Production and Consumption

-Germany

Germany, which we have examined among the developed countries, is shown energy production in Figure 2. In 1990, it has advanced its total energy production of 508582 GWh in a way to continuously increase it without creating much fluctuations over the years. Looking at the year 2016, this value reached 614155 GWh with an increase of 17.19%. In Figure 3, the total energy consumption amounts of Germany are divided into sections in terms of coal, oil, geothermal, temperature, natural gas, biofuel and electricity, and the data is processed and combined into total values. In Figure 4, the energy consumption per capita of Germany is given in ktoe. When these figures are examined, it is seen that there is an annual increase in energy production, but a decrease in consumption, as well as a decrease in annual per capita consumption. This decrease between 1990 and 2016 is around 10%. The decrease in energy consumption is due to public awareness and more efficient use of systems.

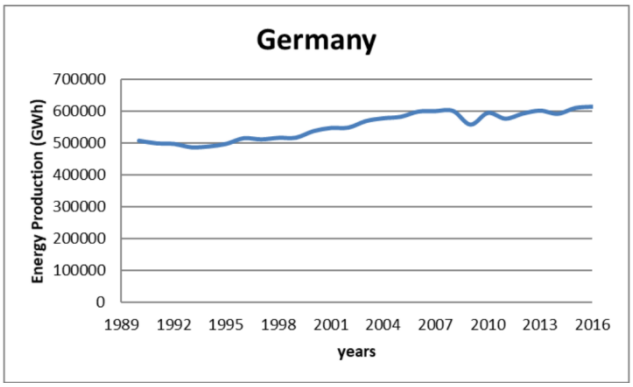

Figure 2. German Energy Production (OECD) [10]

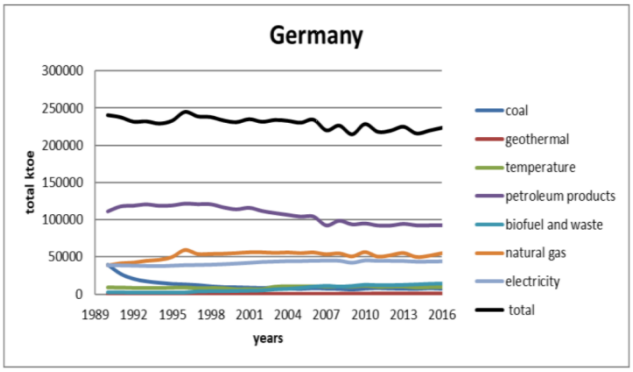

Figure 3. Germany Energy Consumption, Total ktoe (IEA 2019) [11]

Figure 4. Energy Consumption in Germany, ktoe per Capita (IEA 2019) [11]

- France

Energy production amounts are given in Figure 5 in the data of France, which is the other country we examined among the developed countries. When the year 1990 is examined, France, which produced 401151 GWh of energy, increased its energy production to 532943 GWh in 2016 with an increase of 24.73% between 1990 and 2016.

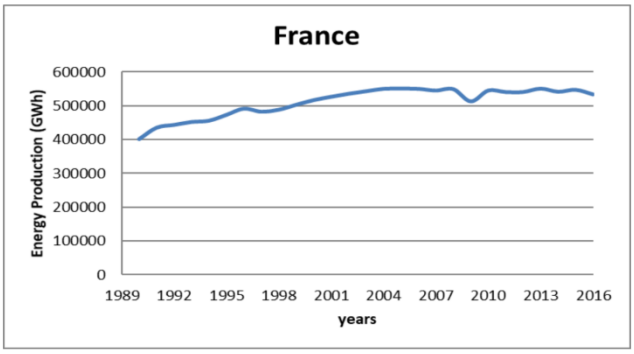

Figure 5. France Energy Production (OECD) [10]

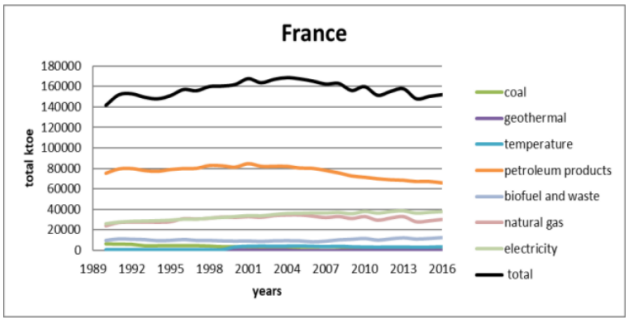

Figure 6. France Energy Consumption, Total ktoe (IEA 2019) [11]

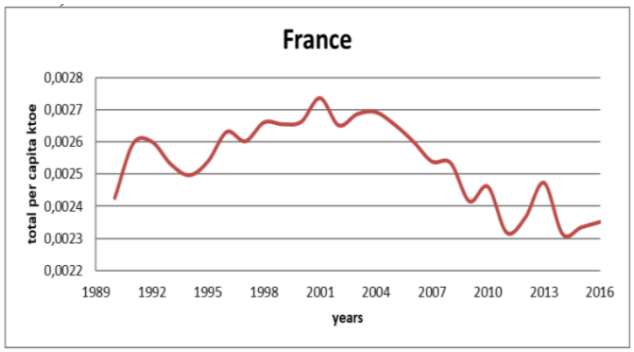

Figure 7. France Energy Consumption, ktoe per Capita (IEA 2019) [11].

In Figure 6, energy consumption data are handled separately in coal, petroleum, geothermal, biofuel, natural gas, temperature and electricity categories and total data entries are processed. In Figure 7., the energy consumption of France is given in ktoe per capita. While energy production increased by 24%, energy consumption started to decrease after 2002. While the per capita energy consumption reached its highest values in 2001, it started to decrease after this year. This decrease between 2002 and 2016 is around 11%. Compared to 1990, the decrease per person is around 3%.

- Netherlands

Energy production data of the Netherlands, which is among other developed countries, are shown in Figure 8. The Netherlands, which produced 69464 GWh of energy in 1990, produced 110984 GWh in 2016 and increased its production by 37.41% between these years.

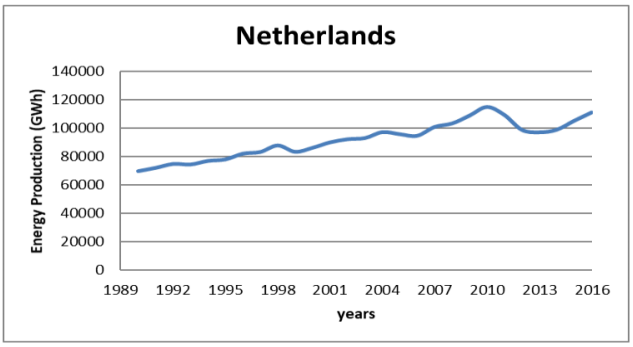

Figure 8. Netherlands Energy Production (OECD) [10]

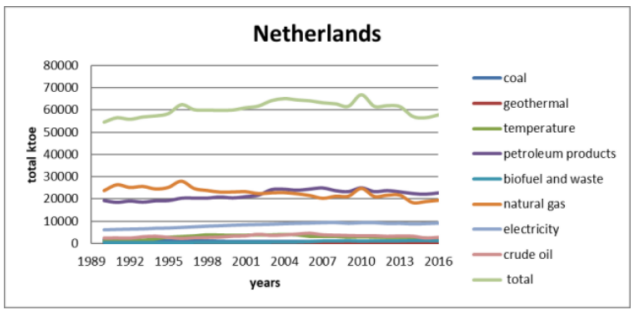

Figure 9. Netherlands Energy Consumption, Total ktoe (IEA 2019) [11].

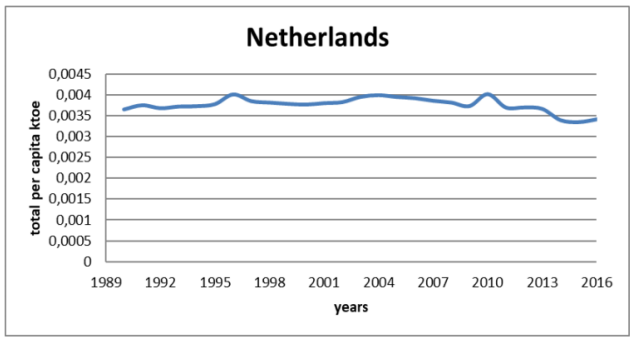

Figure 10. Netherlands Energy Consumption, ktoe per Capita (IEA 2019) [11].

In Figure 9., coal, oil, geothermal, temperature, biofuel, natural gas and electricity data as energy consumption in the Netherlands country are handled in separate categories

and the total ktoe value is reached. Figure 10 shows the per capita energy consumption of the Netherlands. Although it reached the highest data in total energy consumption in 2004, it decreased by 11% between 2004 and 2016. When the period between 1990 and 2016 is examined, it is seen that there is an increase in energy consumption at the level of 5.7%.

- Turkey

Turkey is in the category of developing countries. The energy production amounts shown in Figure 11 were 54232 GWh in our country in 1990 and increased to 261937 GWh in 2016 with an increase of 79.3%.

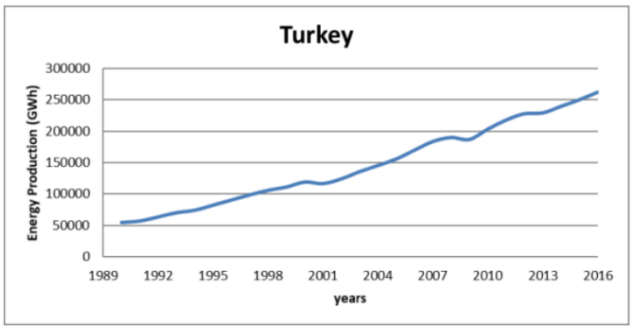

Figure 11. Turkey Energy Production (OECD) [10]

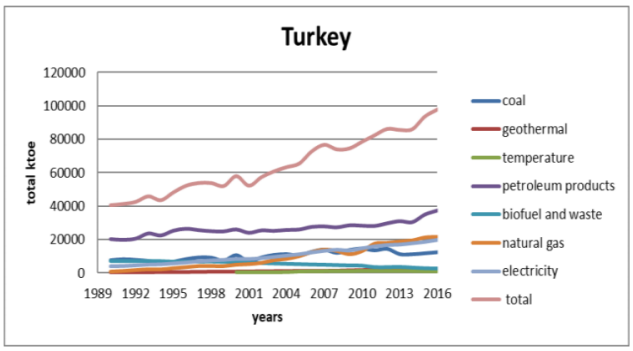

Figure 12. Turkey Energy Consumption, Total ktoe (IEA 2019) [11]

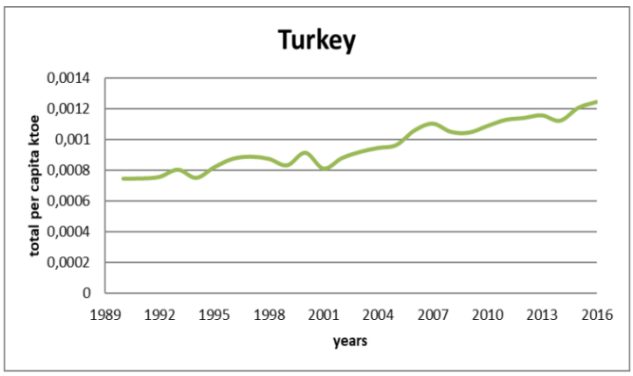

Figure 13. Turkey Energy Consumption, per capita ktoe (IEA 2019) [11].

In Figure 12., the coal, geothermal, temperature, oil, biofuel, natural gas and electricity data used in our country were collected from these data in the form of total consumption. In Figure 13, Turkey's per capita energy consumption amounts are given in ktoe. Turkey, which has been increasing in energy consumption, shows an increase of 58.8% between 1990 and 2016.

- India

When the data of another developing country of India is examined, in Figure 14. the energy consumption amounts of coal, geothermal, oil, natural gas and electricity categories were collected, and total ktoe values were obtained. In Figure 15, the energy consumption per capita for the country of India is given in ktoe. When the energy consumption data of developing India is examined, it has increased in energy consumption by approximately 57.5% from a total value of 242881 ktoe in 1990 to 572289 ktoe in 2016.

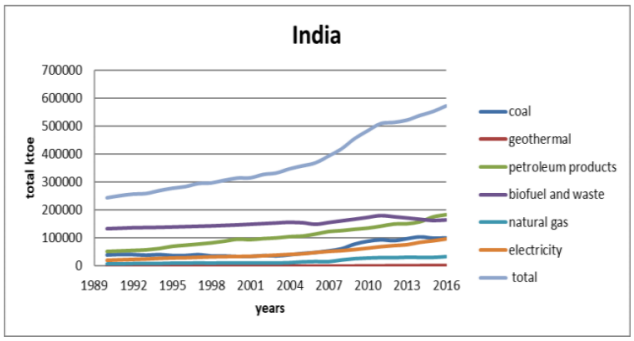

Figure 14. Indian Energy Consumption, Total ktoe (IEA 2019) [11]

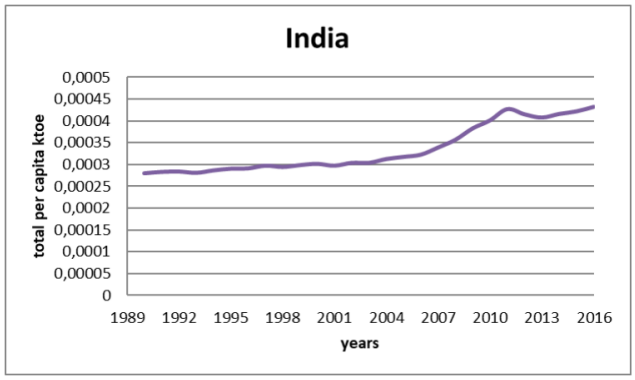

Figure 15. Energy Consumption in India, ktoe per Capita (IEA 2019) [11]

- Brazil

In the data of the last developing country Brazil examined, in Figure 16, the energy consumption data is evaluated separately for coal, geothermal, oil, biofuel, natural gas and electricity types and the total energy consumption is shown. In Figure 17, the amount of energy production per capita in Brazil is given in ktoe. Brazil increased its energy consumption by 50.4% from a total of 111338 ktoe in 1990 to 224269 ktoe in 2016.

As can be seen in Figure 18, where the energy production amounts changing by years and the countries examined are shown together, developed and developing countries exhibited ways that follow their own trends. In terms of energy status of the countries relative to each other, even though Turkey surpassed the Netherlands, it could not approach the energy production amounts of Germany and France. However, Turkey, which exhibits a linear slope in

growth, has shown a growth in energy production by increasing 79.3% over the years.

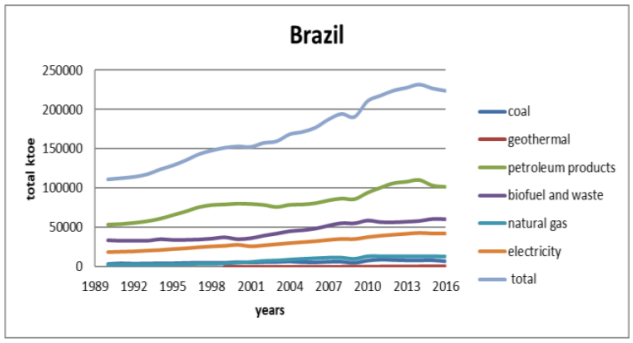

Figure 16. Brazilian Energy Consumption, Total ktoe (IEA 2019) [11]

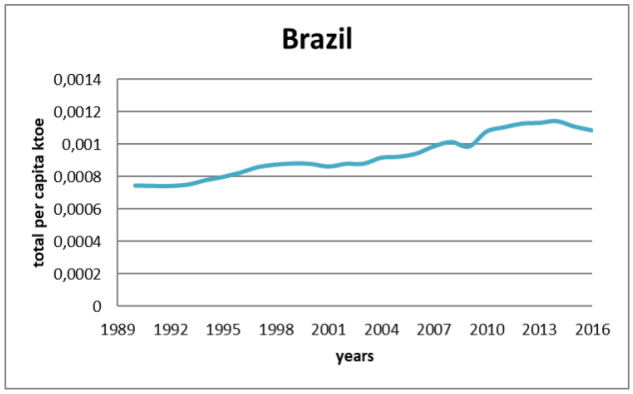

Figure 17. Brazilian Energy Consumption, ktoe Per Capita (IEA 2019) [11].

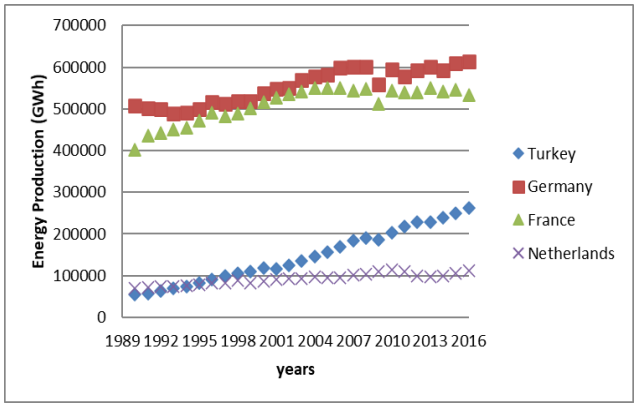

Figure 18. Energy Production (OECD) varying by years [10].

2.2 Renewable Energy Production Amounts

The total renewable energy generation values in GWh of hydroelectric, wind, solar, geothermal and tidal wave energies in Germany, France, the Netherlands, Turkey, India and Brazil between 1990 and 2016 are given in Figure 19. As it can be seen from the figure, it is seen that all countries have increased continuously, even if there are fluctuations when the year 1990 is taken as abasis. Brazil, the country that exhibits the most renewable energy production, increased its total value of 206708 GWh in 1990 by 50.13% between these years and reached 414484 GWh in 2016. Hydroelectric power plants have the biggest role. Looking at Germany, these values increased from 19863 GWh in 1990 to 144006 GWh in 2016, with an increase of 86.21%. In Turkey, on the other hand, this situation increased the total energy production of 23228 GWh in 1990 by 73.79% to 88610 GWh in 2016.

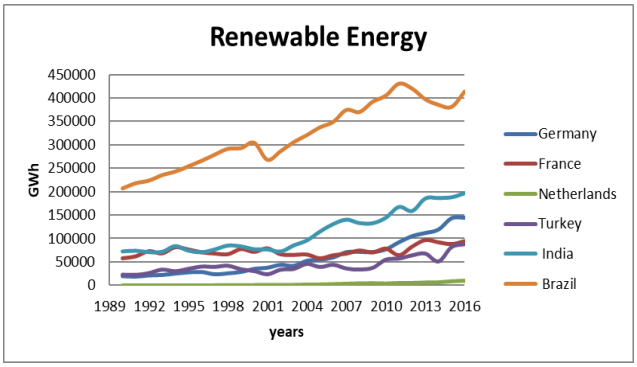

Figure 19. Change by years Renewable Energy Production (IEA 2019) [11].

2.3. Gross Domestic Product (GDP)

There is a relationship between the gross annual product per capita and CO_2 emissions. Both the developed countries and the developing countries, the GDP and per capita CO_2 emissions of the flue gases consisting of greenhouse gases of the fuel-based production sectors operating for all energy production have been analysed. The changes in GDP between 1990 and 2016 for Turkey, Germany, France, Netherlands, India and Brazil countries that we have examined are shown in Figure 20. As can be seen from the figure, developed countries and developing countries have gradually displayed growth rates, showing approximately the same distributions as if they express themselves in separate communities. It is seen that the GDP per capita has increased with the economic growth of Germany, France and the Netherlands, which are developed countries over the years. Likewise, this is the case in developing countries such as Turkey, India and Brazil.

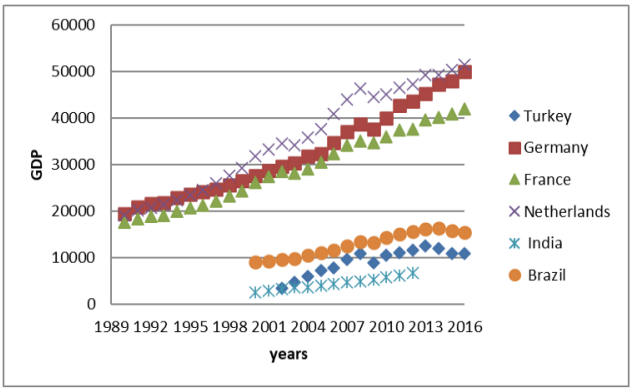

Figure 20. GDP that varies by years (OECD) [10].

In Figure 21. GDP growth rates are given. In the economic crisis that started in the last quarter of 2008 and passed as the 2009 crisis, all countries were affected by the crisis. Although it did not take long for countries to recover after 2009, this crisis in Turkey declined sharply and rose sharply.

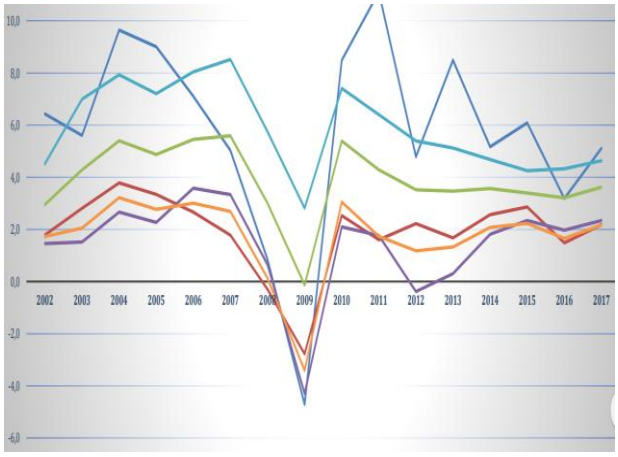

Figure 21. Comparison of GDP Growth Rates [12]

Turkey; ABD; World; AB-28; Developing countries; Developed countries

2.4. CO_2 Emissions

One of the negative effects of economic growth on the environment is CO_2 emissions. Rapidly increasing industrialization has increased the global warming problems and the per capita gas rates of the increase in greenhouse gases. It has been concluded that the relationship between CO_2 emissions and economic growth is realized by the fact that developing countries mostly increase their energy consumption and maintain their high growth rates at the expense of neglecting effective technologies [13]. CO_2, which is formed by the burning of primary fossil fuels containing carbon, accumulates in the atmosphere and causes global warming triggers such as biodiversity losses, ocean level rise, and climatic disturbances. In the countries where CO_2 emissions were measured, growth was initially considered without environmental awareness.

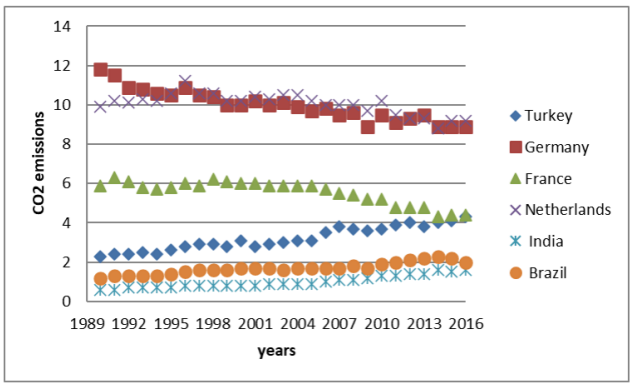

Figure 22. CO_2 emissions (OECD), [10].

In Figure 22, the CO_2 emission values with which the countries are compared are given in terms of tons/person. Developed countries such as Germany, France, and the Netherlands increased their income level at first, and later showed trends that led to environmental awareness and decreased CO_2 emissions. Turkey, India and Brazil countries, that is, these developing countries ignore environmental pollution in order to increase their income levels first. This causes the CO_2 emission rates of developing countries to increase gradually. The figure confirming the Kuznets curve, which is the hypothesis that environmental pollution will increase as the income levels of countries increase, but when a higher income level is reached, environmental awareness is created and environmental pollution decreases, CO_2 emissions decrease in Germany, France and the Netherlands.

3. CONCLUSION

In this study, energy production and consumption values of developed and developing countries, production amounts of renewable energy, GDP values and CO_2 emission amounts are explained with numerical data in the form of graphics. Developed countries initially ignored the environmental pollution caused by greenhouse gases emitted as a result of excessive use of energy consumption by raising their economic levels. As the income levels of these countries increase, considering the sensitivity to environmental awareness, the use of energy with more efficient systems has brought a conscious decrease in energy consumption. Developed countries such as Germany, France and the Netherlands, which give results close to the Kuznets curve, showed the same characteristics by showing a decrease in the slope of the per capita CO_2 emission curves with the per capita energy consumption curves. The main reasons for the decrease in greenhouse gases are the increase in the economic values of the developed countries, mostly from the software sectors within their own country borders, and the production of manpower in foreign countries or the fact that approximately 70% of the energy production is provided by nuclear energy, as in France. European countries have set different targets in various sectors for 2020. These targets are 20% reduction in CO_2 emissions, 20% increase in renewable energy production, 20% increase in emissions and energy efficiency. According to the data interpreted in the graphics, the desired increase and decrease values in the targets set between 1990-2016 were achieved before reaching 2020.

Looking at the developing countries, they are in the part of the Kuznets curve with economic growth. Developing countries such as Turkey, India and Brazil, which attach importance to economic growth values regardless of global warming, air pollution and CO_2 emission values, show a continuous increase in energy consumption per capita and the use of fossil fuels. Looking at the CO_2 emission values in Turkey, it was seen in Figure 22 that greenhouse gas emissions constantly increased with the demand of economic growth. It should not be overlooked that the CO_2 emission values in Turkey, which show a continuous increase in the graph, have caught the CO_2 emission values of France. Although the data we have belongs to the years 1990-2016, it can be thought that CO_2 emission values will decrease with the

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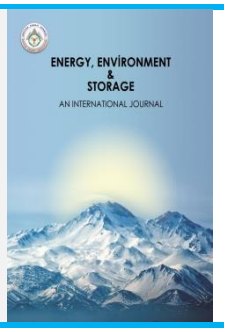

Application in Virtual System Modelling (VSM) of Sensored Pm BLDC Motor Drive Using Two Technologies of Processors PIC16F877Aand Arduino Uno R3

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ABSTRACT. This paper presents the simulation of a 3-phase Permanent Magnet Brushless DC (PM BLDC) motor drive. For the studied drive system in this paper, pulse width modulation (PWM) control has been implemented for a 60-degree six-step trapezoidal PM BLDC motor drive. The used processor is Arduino and PIC16F877A, which is a common, flash-able, and low-cost microcontroller unit (MCU) with functions to perform commutation sequence, rotating direction control, speed control and reading Hall sensor signals, and calculating RPM and duty cycle of the PWM outputs signals depending on variable speed. The controlling technique uses sensored type in order to make this design suitable for low-speed and high-speed applications plus control simplicity. In this paper, The application of Proteus Virtual System Modelling (VSM) software as a real-time simulation tool is introduced to model the performance of a 3-phase Permanent Magnet Brushless DC motor drive before hardware implementation. Expected results can be monitored and analyzed throughout the virtual simulation of all components. The usage of Proteus VSM enables shorter product development time, thus reducing development costs for industrial applications.

Keywords:Permanent magnet; BLDC motor; Controller; PWM; Proteus VSM; Arduino.

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1. INTRODUCTION

In the literature, there are different types of DC motors such as Brushless Direct Current Motor (BLDC) [1], Permanent Magnet Synchronous Motor (PMSM) with a sinusoidal waveform of the Back EMF [2], stepping Motors [3], and Brushed DC motor (BDC) [4]. Stepping Motors are ideally suited for open-loop positioning, also known as BLDC motor sensorless. BLDC machines are the most obvious candidate for high-speed applications, and they are closed-loop positioning by using Hall sensors. BLDC motors are considered one of the best motors that are gaining popularity around the world [5]. BLDC motors are used in industries such as appliances, automotive, aerospace, consumers, medical, industrial automation equipment, and instrumentation [6]. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors, such as they have (i) better speed versus torque characteristics, (ii) higher dynamic response, (iii) higher efficiency, (iv) longer operating life, (v) noiseless operation, (vi) and higher speed ranges [7]. In addition, the torque ratio is high, and it is delivered to the size of the rotor, which makes it useful in some applications where weight and space are critical factors.

The contribution of the designed circuit is by integrating two different technologies of processor (PIC16F877A) from microchip and Arduino from Atmel. The first processor measures the speed variation of the BLDC motor and displays it on the LCD screen. The result is compared to the second processor that measures speed via VSM (proteus), which provides independence. By using two processors, the performance of the system is improved, and the size of memory is increased. Hence, the system becomes more multitasking.

2. CONSTRUCTION AND OPERATING PRINCIPLE

BLDC motor consists of stator, rotor, and position sensor as shown in Figure 1. The rotation of the BLDC motor requires position feedback of relative rotor position. Mostly used BLDC motor uses Hall sensors as the position feedback [8]. In order to produce a rotating field (driving torque), respective phases of the stator have to be turned on and off in sequence through the six switches (usually MOSFET or IGBT) of the three-phase full-bridge

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inverter, depending on the position of the rotor. Position signals from the three Hall sensors are fed back to the controller. Hall signals carry either 0V (logic low) or +5V (logic high) depending on the rotor position.

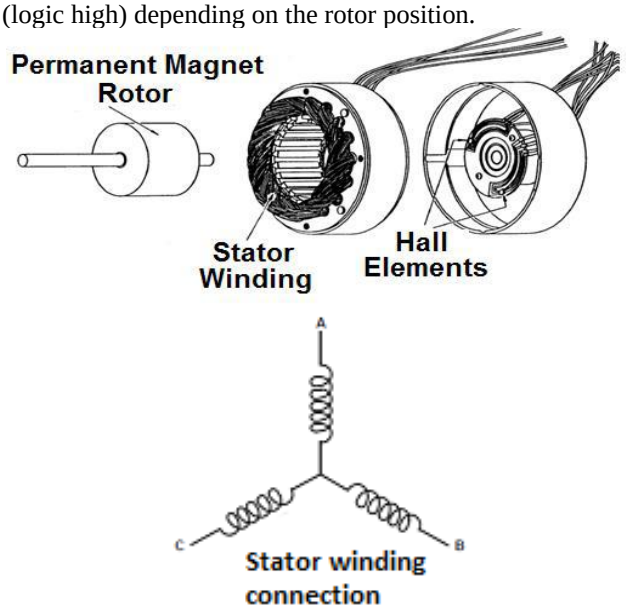

Figure 1. Different parts of sensored BLDC motor [8].

BLDC motors are a type of synchronous motor. It means that the magnetic fields generated by both stators, and rotors, rotate at the same frequency. In addition, they do not experience the "slip" which can be found in induction motors.

2.1 Stator

The BLDC motor's stator consists of stacked steel laminations with windings placed in the slots that are axially cut along the inner periphery. Traditionally, the stator resembles the one of an induction motor. However, the windings are distributed in a different manner. Most BLDC motors have three stator windings connected in a star fashion. Each winding has many interconnected coils. At least one coil is placed in the slots, and it is interconnected to other coils to form a winding. Each of these windings is distributed over the stator periphery to form an even number of poles. There are two types of stator windings variants, trapezoidal and sinusoidal machines (also called motors). The difference is made based on the interconnection of coils in the stator windings to give the different types of back Electromotive Force (EMF). The trapezoidal motor provides a back with EMF that forms a trapezoidal waveform, as in Figure 2, while the sinusoidal motor gives a back EMF which forms a sinusoidal waveform, as shown in Figure 3.

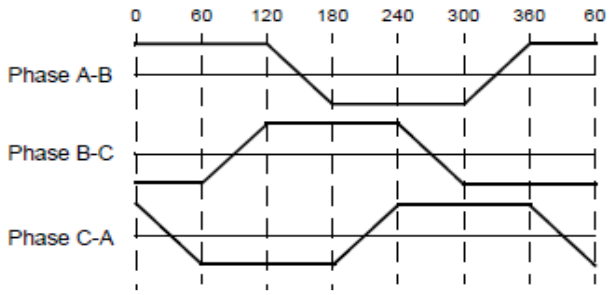

Figure 2: Trapezoidal back EMF [9].

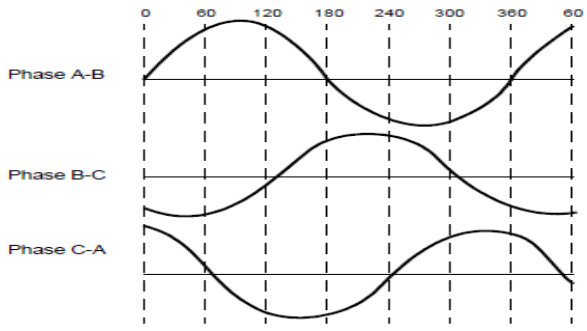

Figure 3: Sinusoidal back EMF [9].

In addition to the back EMF, the phase current also has trapezoidal and sinusoidal variations in the respective types of motors. This makes the output torque by a sinusoidal motor smoother than the one of the trapezoidal motors. However, this comes with an extra cost, as the sinusoidal motors take extra winding interconnections because of the coil's distribution on the stator periphery, thereby increasing the copper intake by the stator windings.

2.2 Rotor

The rotor is made of a permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Permanent magnets are traditionally made of Ferrite magnets. Rare earth alloy magnets are gaining popularity as technology advances. The ferrite magnets are less expensive, but they have the disadvantage of low flux density for a given volume. In contrast, the alloy material has a high magnetic density per volume and enables the rotor to compress further for the same torque. These alloy magnets improve the size-to-weight ratio and give higher torque for the same size motor using ferrite magnets. Figure 4 shows cross-sections of different arrangements of magnets in a rotor.

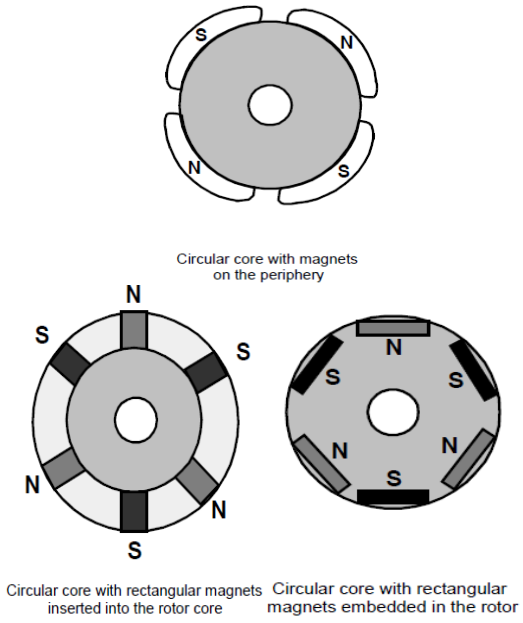

Figure 4: Rotor magnet cross-sections [9].

2.3 Hall Sensors

The Hall Effect theory is described when a current-carrying conductor or a semiconductor is introduced to a perpendicular magnetic field. A voltage can be measured at the right angle to the current path. This effect of obtaining a measurable voltage is known as the Hall Effect. Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. The rotor position should be determined and known in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall effect sensors embedded into the stator. Most BLDC motors have three Hall sensors embedded into the stator on the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. The exact sequence of commutation can be determined based on the combination of these three Hall sensor signals.

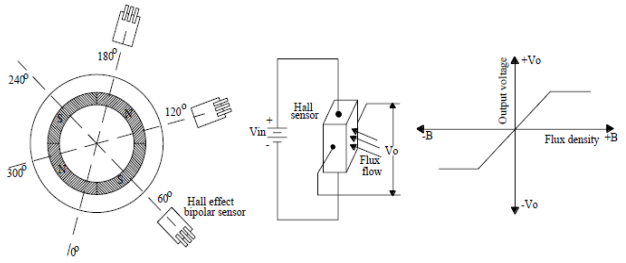

Figure 5: Hall sensor [10].

3.MATHEMATICAL MODELING OF THE SPEED TORQUE

After the short introduction of each part of the motor, it is necessary to have a mathematical model of the system which will be described in this section.

Speed torque characteristics of a BLDC motor can be realized from the EMF and voltage equations of the motor. The EMF equation of the BLDC motor is quite simple and resembles the conventional DC motor. Induced EMF in a single coil can be expressed in Equation (1), [10-12].

$$e_{ph}= 2B_g r l T_{ph} w_m \quad (1)$$

Where,

e_{ph}	EMF generated per phase in Volt
B_g	Flux density of air gap in wb/m2
r	Radius of air gap in mm
l	Length of armature in mm
T_{ph}	Number of coil turns per phase
w_m-	Angular velocity in mechanical rad/sec

Considering another coil connected with slot angle gives equal magnitude. Hence, the resultant induced back EMF per phase is shown in Equation (2), [10-12].

$$e_{ph} = 4B_g r l T_{ph} w_m \quad (2)$$

By considering the back EMF constant ($K_m = 4B_g r l T_{ph}$), the generated back EMF becomes as shown in Equation (3). The voltage equation of BLDC is similar to conventional DC motor and it is presented in Equation (4), [10-12].

$$e_{ph}= K_m w_m \quad (3)$$

$$V = 2e_{ph} + 2IR_{ph} + 2V_{dd} \quad (4)$$

where:

V	Supply voltage in Volt
I	Armature current in Amp
R_{ph}	Armature resistance per phase in Ohm
V_{dd}	Voltage drop of the device in Volt

Usually,the voltage drop is neglected, then armature current can be expressed by Equation (5). Equation (6) is obtained by substituting Equation (3) into Equation (5). Equation (6) is obtained by substituting Equation (3) into Equation (5), [10-12].

$$I=(V - 2e_{ph})/ 2R_{ph} \quad (5)$$

$$I= (V-K_m W_m)/2R_{ph} \quad (6)$$

From Equation (6), the speed of the motor can be expressed as in Equation (7), and the input power of the motor is presented in Equation (8), [10-12].

$$w_m= (V-2IR_{ph})/K_m \quad (7)$$

$$VI= 2 Ie_{ph} +2I^2R_{ph} +2 V_{dd} I \quad (8)$$

where:

VI	Electrical power input in Watts
$2Ie_{ph}$	Power converted as mechanical (Pm) in Watts
$2I2R_{ph}$	Resistive loss of armature winding in Watts
$2V_{dd}I$	Power loss of device in Watts

Hence the mechanical power developed in the motor is described in Equation (9), and the torque developed in the motor is given by Equation (10), [10-12].

$$P_m = (4 B_g r l T_{ph}) w_m I \quad (9)$$

$$T=P_m/W_m \quad (10)$$

where:

T	Torque developed from the motor in Nm
P_m	Power developed from the motor in Watts
W_m	Speed of motor in rad/sec

By substituting Equation (9) into Equation (10), the final developed torque can be written as in Equation (11), [10-12].

$$T=4B_g r l T_{ph} I \quad (11)$$

By considering the torque constant ($K_m = 4B_g r l T_p I$), the developed torque of the motor becomes equal to Equation (12), [10-12].

$$T= K_m I \quad (12)$$

From this observation, the back EMF constant and the torque constant of the BLDC motor are the same as K_m. Hence the work of BLDC becomes similar to a conventional DC motor. The speed-torque characteristic of a BLDC is shown in Figure 6.

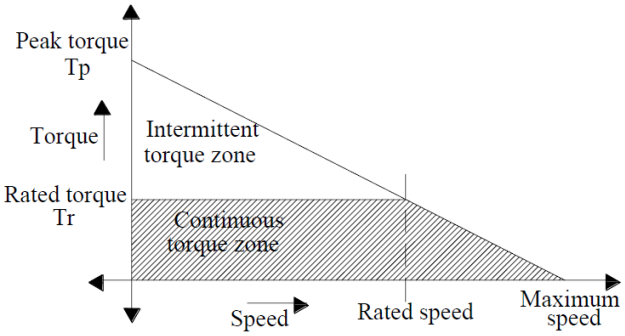

Figure 6: Torque versus speed curve [10].

4. CIRCUIT DESIGN

4.1. Circuit Design and Operation in Proteus (VSM)

Figure 7 presents the design and operation of a BLDC motor drive circuit using Proteus VSM. The digital pulses from Hall sensors are fed to the microcontroller. The external interrupt is generated on each bit change of any of the three Hall position signal inputs. Special interrupt on bit change is an inherent feature of the Arduino microcontroller, which is useful in designing the motor control algorithm. As soon as any bit change occurs on any one of the three Hall input signals, the program execution sequence skips interrupting address. Six PWM signals are required to drive six MOSFET gates of the three-phase full-bridge inverter. This inverter directly drives the three phases of the BLDC motor. Depending on the rotor position, respective PWM channels are turned on, which in turn drive the respective phases of the BLDC stator through the MOSFETs of the inverter. The proper commutation sequence Clockwise for the respective Hall bit pattern should be stored in a look-up table format in the controller after carrying out proper experiments on the motor. This sequence allows appropriate phase energizing for one-directional rotation continuously performing electronic commutation. For ease of understanding, the developed scheme has been sectionalized into blocks and presented in Figure 8.

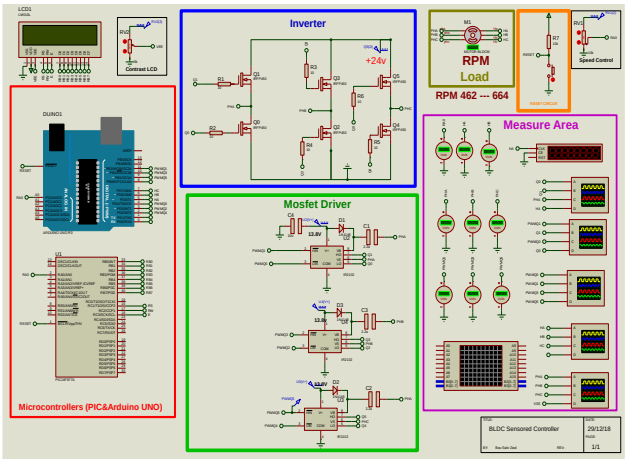

Figure 7: Operation of a BLDC motor drive circuit.

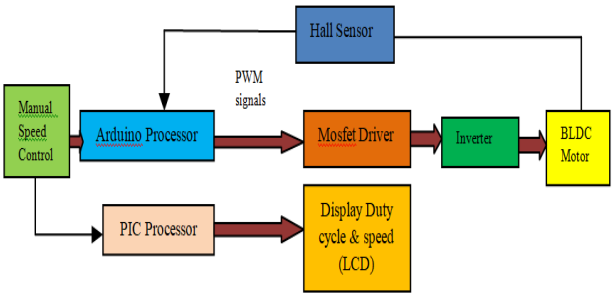

Figure 8: Schematic blocks of the controlled circuit.

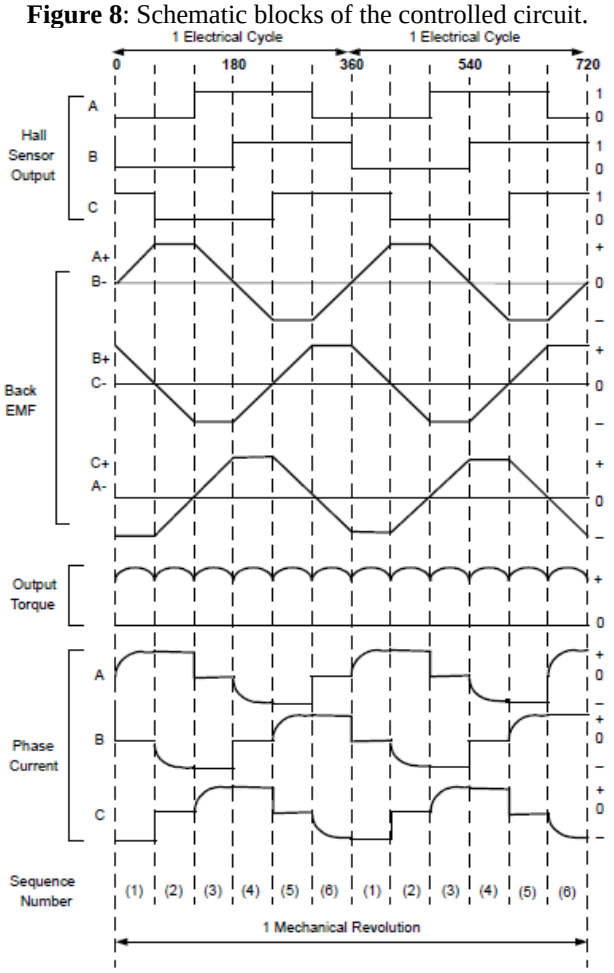

Figure 9: Relationship between the sensors outputs and the required motor drive voltages for phases A, B, and C with Back EMF current signals torque [9].

To drive this motor, we need a 3-phase bridge, which has 6 MOSFETs. The general circuit schematic diagram of the 3-phase bridge is presented in Figure 8. Figure 9 shows the relationship between the sensors' outputs and the required motor drive voltages for phases A, B, and C with Back EMF current signals torque.

According to the Hall Effect sensors, the 3-phase bridge is controlled, as shown in Table 1. In the circuit, there are three IR2102 gate driver IC; each one is used to drive one high side MOSFET HIN and one low side MOSFET LIN. The 10k potentiometer is used to control the brushless DC motor speed, and it is controlled using the PWM technique (PWM high sides only). Any time there is one active high side MOSFET and one active low side MOSFET, that means there is always one active PWM pin (Arduino pin 2, 3, and 4). The table below summarizes the active

Arduino pins according to the hall effect sensors states (pins: 8, 9, and 10).

Table 1. Pins of Arduino processor.

Pins of Arduino Processor										
Step	Position	Hall Sensor of BLDC			PWM signals drive upper Mosfet of inverter		PWM signals drive lower Mosfet of inverter			
Sequence	degree	HA (5)	HB (6)	HC (7)	PWM Q1 (11)	PWM Q3 (10)	PWM Q5(9)	PWM Q0(4)	PWM Q2 (3)	PWM Q4(2)
1	60	**0**	**0**	**1**	**ON**	**0**	**0**	**1**	**0**	**0**
2	120	**0**	**0**	**0**	**ON**	**0**	**0**	**0**	**1**	**0**
3	180	**1**	**0**	**0**	**0**	**0**	**ON**	**0**	**0**	**1**
4	240	**1**	**1**	**0**	**0**	**0**	**ON**	**1**	**0**	**0**
5	300	**1**	**1**	**1**	**0**	**ON**	**0**	**1**	**0**	**0**
6	360	**0**	**1**	**1**	**0**	**ON**	**0**	**1**	**0**	**0**

For application purposes, a simple PWM code is written in an Arduino processor because an active PWM signal is needed on pins 9, 10, and 11 (only one is active at a time). Timer2 module is used in this case. The ADC module is configured to read from channel A0 only. The Arduino interrupts on change,and it activates for pins 5, 6, and 7 (hall effect sensors inputs) for better commutation. PORTB are Arduino uno pins: 8 … 13. PORTD are Arduino uno pins: 0 … 7. Then, the PIC16F877A processor is used to measure the speed of the BLDC motor and the duty cycle of PWM control signals, which depend on variable speed. After that, the speed of the BLDC motor and the duty cycle of the PWM control signals are shown on an LCD display 2lines 32 characters (2x16). Figure 10 presents the flowchart of the code written in the Arduino and PIC16F877A processor.

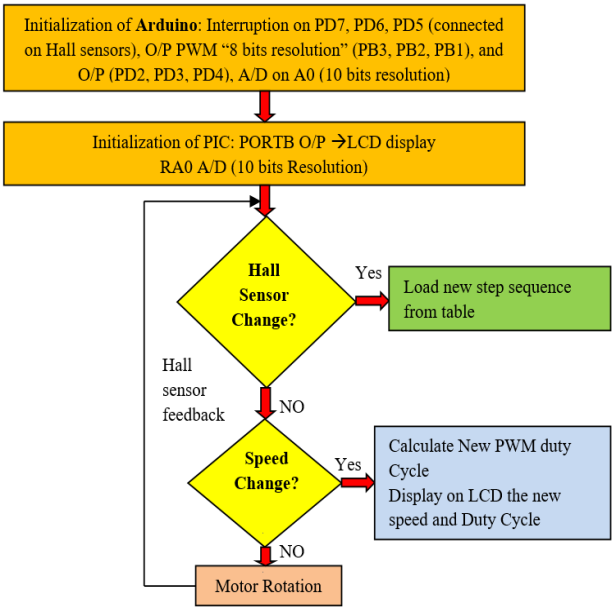

Figure 10: Flowchart of the code written in Arduino and PIC16F877A processor.

4.2. Different types of control and selected technique

In the PWM, the voltage supply is chopped at a fixed frequency with a duty cycle depending on the current error. Therefore, both the current and the rate of change of the current can be controlled. The two-phase supply duration is limited by the two-phase commutation angles. The main advantage of the PWM strategy is that the chopping frequency is a fixed parameter. Hence, acoustic and electromagnetic noises are relatively easy to filter. There are also two ways of handling the drive current switching: hard- and soft-chopping. In the hard-chopping technique, both phase transistors are driven by the same pulse signal: the two transistors are switched on and off at the same time. The soft chopping approach allows not only a control of the current and of the change rate of the current but a minimization of the current ripple as well. In this soft chopping mode, the low side transistor is left ON during the phase supply, and the high side transistor switches according to the pulsed signal. In this case, the power electronics board has to handle six PWM signals. The duty cycle determines the speed of the motor. The desired speed can be obtained by changing the duty cycle. The PWM in the microcontroller is used to control the duty cycle of the BLDC motor. The average voltage in Equation (13), is obtained for various duty cycles. As the duty cycle percentage decreases, the average voltage also decreases from the supply voltage, as shown in Equation (14). In this case, the duty cycle is defined as the percentage of time the motor is ON. Where, Duty Cycle is in (%), the Pulse Width is equal to the time when the signal is ON or on a higher state. The period is in seconds, and it is equal to the time of one cycle.

$$Average\ voltage = D*V_{in} \quad (13)$$

$$Duty\ Cycle = 100\%*Pulse\ Width/Period \quad (14)$$

5. RESULTS

5.1. Simulation

By simulating the electronic circuit in figure 7, we can observe the operation of the BLDC motor. When we change the speed of the motor via a potentiometer, the duty ratio will change also, and we observe the modification on DSO and LCD. The simulation results of BLDC-M using Proteus Design are shown in Figures 11 to 19. The signal outputs of the PWM measured by the DSO are shown in figure 11. By changing the motor speed, the frequency of the PWM signal should be much higher than the motor's frequency (at least 10 times depending on the change speed. The average voltage applied to the stator reduces; hence, speed control is achieved. To obtain the desired PWM, the program is written for changing the duty cycle ratio. For the unipolar PWM technique, the triggering is applied at either the lower or upper pair of the inverter.

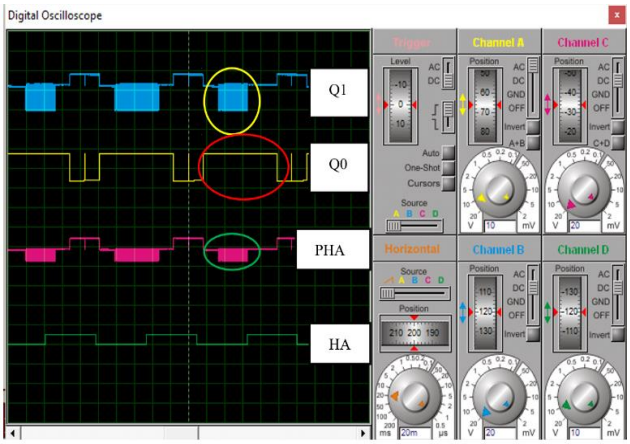

Figure 11: Signal outputs of the PWM measured by the DSO.

In Figure 11, the yellow (Q0) and red (Q1) circles show the unipolar PWM technique, in which the triggering is applied on the upper MOSFET of the inverter (the amplitude of this signal is +12V). PHA presents phase A that feeds the coil A of the BLDC motor's stator. The PWM signal can be seen when Q1 output is in the PWM mode (the amplitude signal is +24 Volt). HA is one of the three Hall sensor response signals (the amplitude is 5V). Figure 12 shows a closer look at the PWM in Figure 11, where the PWM period and duty cycle at maximum speed.

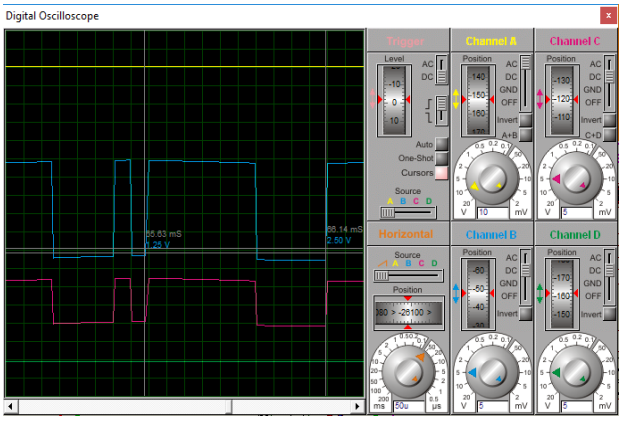

Figure 12:A closer look at the signal outputs of the PWM measured by the DSO.

5.2. Calculation of the period and duty cycle at maximum speed

In this case, we assume that the base time of DSO is 50µs. The period will be 500 µs (50µs x 10). The frequency is $F_{measured}$=2 Khz (1/500µs=2000 Hz). The minimum f(PWM) signal is 500 Hz (10 x 50 Hz). Therefore, F (measured) > f(PWM) and the duty cycle is about D=60 % (T_{on} /T=6/10) as presented in Figure 13.

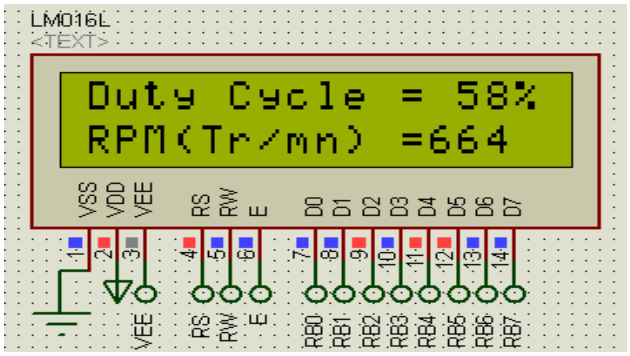

Figure 13: Display of duty cycle and RPM at max speed.

5.3. Calculation of the period and duty cycle at medium speed

In Figure 14, by reading between cursors, the period becomes T_{total}=510µs, (273.66ms - 273.16ms = 0.51ms). It is important to note that the PWM frequency is stable, but the duty cycle changes, and it becomes equal to D'=28% (0.14ms/0.5ms) as in Figure 15. T_{on}=0.13ms (273.16ms - 273.03ms). The signal on pin PWMQ1 is depicted in Figure 16.

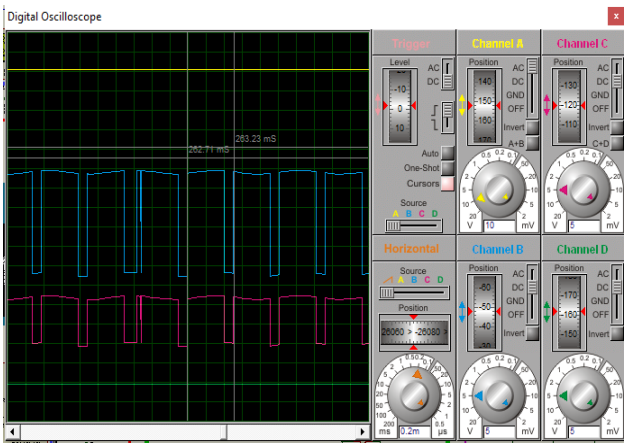

Figure 14: Signal outputs of the PWM at medium speed.

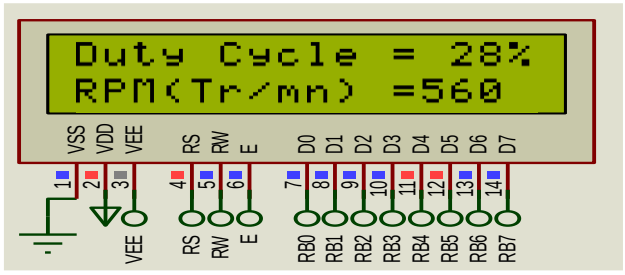

Figure 15: Duty cycle and RPM calculated by the software.

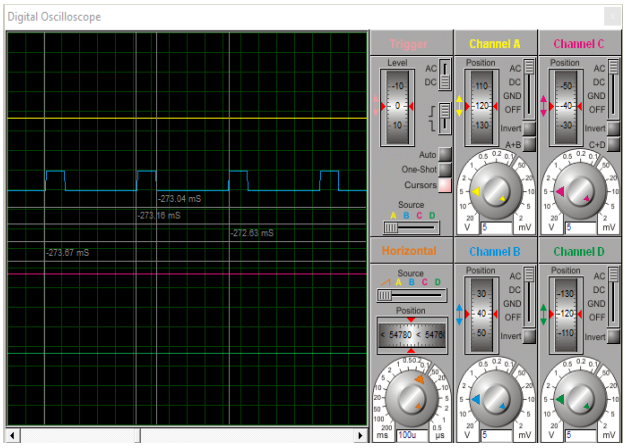

Figure 16: Signal on pin PWMQ1.

5.4. Calculation of the period and duty cycle at minimum speed

In figure 17, the LCD display shows the speed and the duty cycle when the RA_0 = 0V. Figure 18 shows the three phases PHA, PHB, and PHC, when these signals have a shape of trapezoidal Back EMF.

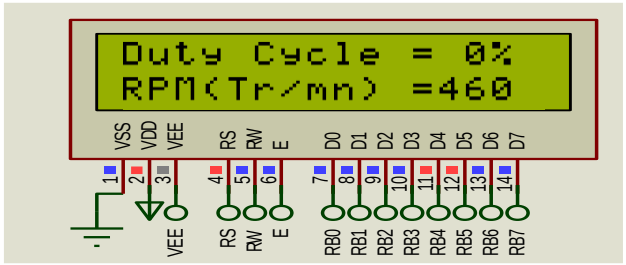

Figure 17: Duty cycle at minimum speed.

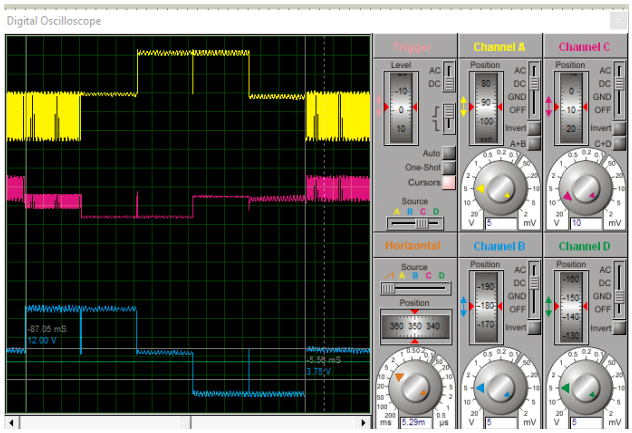

Figure 18: Phase A, B, C signals of BLDC motor.

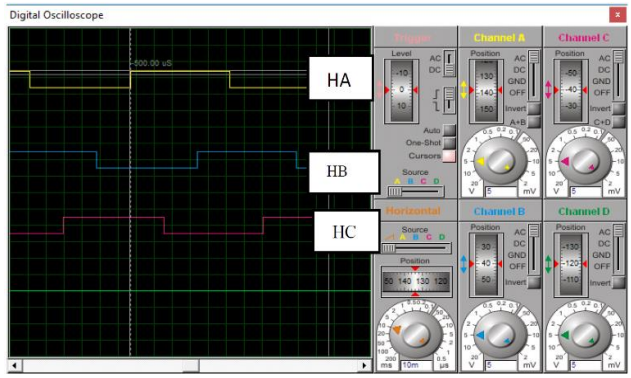

Figure 19: Response of Hall sensors depending on BLDC motor position.

5.5. Reverse rotation direction of BLDC motor

To reverse the rotation of the BLDC motor, we swap two Hall sensor wires (HB & HC) and two-phase wires (PHB & PHC) by using two relays controlled via Arduino (PB4 & PB5), which is considered as a hardware solution. The software solution that is used in our circuit can work by swapping the signals generated on (PWMQ5 & PWMQ3) and (PWMQ2 & PWMQ4). At the same time, detecting signals received by HB instead of HC and vice versa without changing wire connections of the circuit but by swapping a loop function in Arduino program when activating reverse direction by the user.

6. CONCLUSION

In this paper, two different technologies of processors are used, PIC and Arduino, in the same simulator (Proteus). Results show that it is beneficial to combine the two processors to enhance the control system of the BLDC motor with Hall effect sensor and BLDC-motor sensorless (Stepper Motor). The proposed combination enlarges the size of the memory program. Hence, it is possible to apply this method in order to reduce ripple torque by using Matlab/Simulink, and convert the solution of the Simulink to Arduino and PIC processors. This can be done by making segmentation of program and each processor execute a part of the task. The communication between multiple processors enhances the efficiency of analysis by executing complex mathematical equations like integral and differential (PID) and enriches the interface communication with different terminals. The disadvantages of the combination of Arduino and PIC in the same circuit is presented as follows, (i) each microcontroller has a specific current limit and input voltage (e.g., PIC's current limit has an average of 25mA, while Arduino's current limit has an average of 40 mA); (ii) the input voltage in Arduino should be between 7-12V, while it should not exceed 5V for the case of a PIC. Therefore, we should take into account these differences in wiring connections. This paper presents a prototype work that realizes a solution to the control system. Finally, double verification is made by reading the results from DSO (oscilloscope) and confirming them using the proposed algorithm through a second processor (PIC) with a numerical solution. Therefore, the proposed method becomes easier for the user and more efficient.

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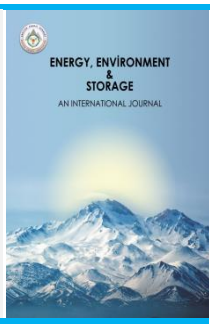

Thermal Analysis of a Li-Ion Battery using FloEFD Software

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ABSTRACT. In the presented study, a thermal analysis of a lithium-ion battery was carried. The battery consists of 6 Series 2 parallel, 12 lithium-ion (NCA 18650) batteries. Liquid water was used as a refrigerant in the thermal analysis of the battery. After designing in SOLIDWORKS computer-aided design program, performance of the battery module was investigated with the help of SIEMENS FloEFD program which is a computational fluid dynamics program. The simulations were performed under steady-state conditions by using the k-epsilon turbulence model. The results bring out that the highest temperatures were occurred at the busbars and the liquid cooled batteries can operate efficiently at a temperature of 27-28°C.

Keywords: Li-Ion Battery, FloEFD, Thermal Analysis, Numerical Simulation

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1. INTRODUCTION

Due to the ever-increasing customer demands that push the limits of our imagination, a rapid technological consumption is experienced in every field from transportation to communication, from health to defense. At the presented time, it is known that almost every individual has at least one of the portable electronic devices (computers, mobile phones, cameras, cameras, MP3 players, CD players, DVD players, radios, televisions) for fast, efficient and easy communication [1]. In addition, most of the electrical appliances we use at home are becoming wireless. The basic condition for long-term and effective use of all these wireless portable electronic products is to have an energy source with high energy density, safe, long-lasting, easy to maintain, rechargeable in a short time and does not harm the environment. Lithium-ion batteries are widely used today in portable electronics and electrical equipment due to their superior features [2]. For this reason, studies, research and developments on lithium-ion batteries have increased over the years.

The biggest factor affecting the performance of batteries, one of the main parts of electronic devices and electric vehicles, is temperature. Too high or too low temperature can directly affect battery performance and reliability, leading to a capacity reduction. And in extreme cases, it can cause permanent deterioration even with thermal runaway [3,4]. Therefore, efficient and stable thermal management is key to battery systems. At the presented time, CFD technology has developed rapidly with the improvement of numerical computing method and computer performance [5]. Computational fluid dynamics programs can be used to investigate and make improvements to the heat flux fields and thermal management of coils. According to the heat transfer medium, the cooling method of the battery thermal management can be divided into three different types, respectively air cooling, liquid cooling and phase change cooling [6]. Xu and Sun [7], used CFD methods to study the air-cooled battery pack based on field synergy principle. The results showed that raising air speed and decreasing air temperature can increase the field synergy number, thereby improving the heat dissipation performance of a battery. Saw et al. [8], utilized CFD method to analyze the air cooled battery pack containing 38, 120 cells. The simulation results indicated that increasing the cooling air flow rate will cause higher heat

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transfer coefficient and pressure drop [9]. To build a whole battery pack and its cooling system is much more difficult than to build a single battery module with a liquid cooling plate [10].

Peng et al. [11], examined the optimal configuration of an air cooling (AC) system for a cylindrical battery pack. As a result, different configurations have been introduced so that the battery can operate at a more favorable temperature.

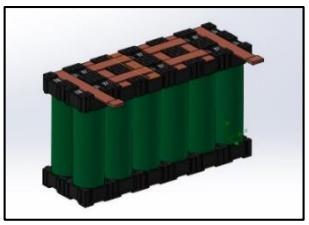
In this study, the thermal performance of a battery cooled with liquid (water) cooling was analyzed numerically with the help of SIEMENS FloEFD program.

2. MATERIALS AND METHODS

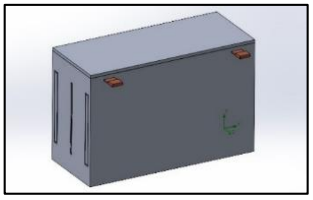
In this study, it was aimed to investigate the thermal performance of a battery cooled with liquid (water) cooling. In line with this aim, the thermal model of lithium-ion batteries was examined, and the temperature values of the battery were calculated. A lithium-ion battery pack and cooling system firstly was designed with SOLIDWORKS computer-aided design program. The liquid cooled battery module is generally composed of batteries, bus bars, liquid cooling system and other parts. The operation of the liquid cooling system is directly related to the performance and efficiency of the battery module.

In Figure 1, the sequence of the design of 12 batteries (6 series 2 parallel) is shown in section a. In Figure 1, the arrangement of the busbars is shown in part b. In Figure 1, in part c, an outer aluminum case is designed.

a.



b.



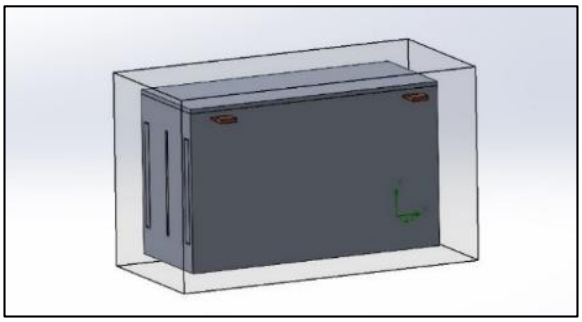
c.

Figure 1. The design stages of the battery **a.** Arrangement of batteries **b.** Arrangement of busbars and batteries **c.** Outer casing

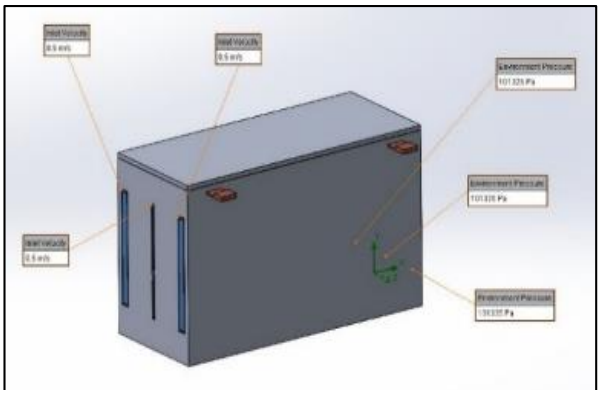
The lithium-ion battery, which was designed in the SOLIDWORKS program, was created in the SİEMENS FloEFD program. In the thermal model preparation part, the computational domain in which the analysis will take place has been created. After the computational domain has been established, the boundary conditions of the lithium-ion battery are determined.

In Figure 2, computational domain was created in part a to perform battery analysis. In Figure 2, boundary conditions are entered in part b. The inlet velocity of the liquid (water) used as a coolant is given as 0.5 m/s. Its output is defined as ambient pressure. 12 Amps current is defined in the input part of the battery. The output voltage is also defined as zero.

Equivalent circuit model is used while performing battery analysis in Siemens FloEFD software. In the equivalent circuit model, the battery is subjected to a power-current test. The change of state of charge (SoC) in these tests and the temperature distribution on the battery are shown. In the equivalent circuit model in the Siemens FloEFD program, the current must be active in order to complete the circuit working behind the program and to see the temperature distribution in the batteries. In order to complete the circuit on the program and to activate the current, the voltage value is given as zero (0).



a.



b.

Figure 2. a. Computational domain
b. Boundary conditions

After determining the computational domain and boundary conditions of the lithium-ion battery, the meshing part was started. In the lithium-ion battery, the global mesh and local mesh was discarded. Figure 3 shows the mesh structure created in the coil. As can be seen in the figure, mesh density has been established on important places where the analysis will take place

(cooling system, etc.) There are a total of 955,000 elements in the mesh structure created. After completing the computational domain, boundary conditions and mesh structure, the thermal analysis of the battery was carried out.

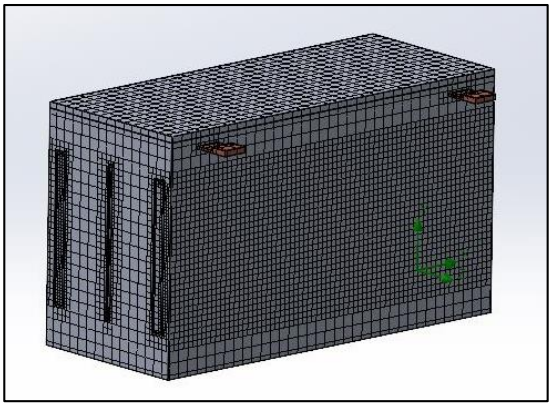


Figure 3. Mesh Structure

3. CONCLUSIONS

Thermal analysis of the lithium-ion battery was carried out. Thermal analysis results were given in Figures 4 and 5. The results clearly show the heat zones of the battery cells and the distribution of this heat in the battery.

Temperature distribution in the outer aluminium case of battery was plotted in Figure 4. As is apparent from this figure, temperature intensity is higher especially at the ends of busbars.

Figure 5 shows the temperature distribution inside the battery in order to see clearly thermal analysis results of the internal parts of the battery (batteries, busbars, battery bed, etc.). The liquid-cooled system used in the battery pack has enabled the batteries to work efficiently at 27-28°C. Temperature is higher in the busbars, inlet and outlet areas of the battery.

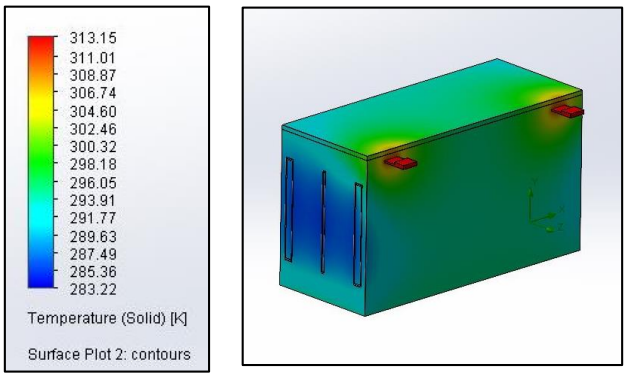


Figure 4. Temperature distribution in the outer aluminum case

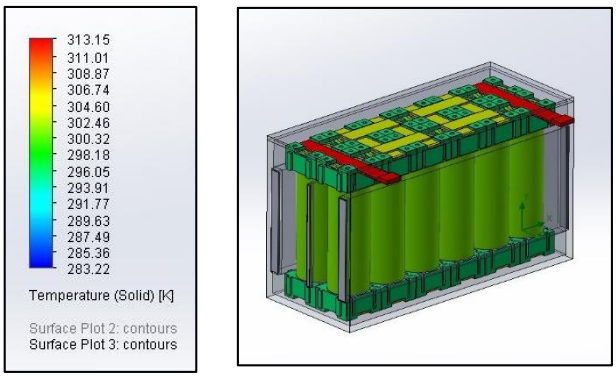


Figure 5. Temperature distribution inside the battery

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Evaluation of Tea Factory Wastes in Energy and Other Areas - A Review

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ABSTRACT. Today, orientation towards alternative energy sources has gained great importance. Biomass resources are easily available, plentiful, inexpensive, environmentally friendly and sustainable renewable energy sources. Biomass resources have the potential to be used not only for energy production but also in many different fields. One of the sources of biomass is the tea factory wastes (TFW) released during black tea production. This resource, which has no economic value, can be used in many different fields and forms. In this study, these studies made with tea factory wastes were compiled and gathered under five main headings. These are agriculture and animal husbandry, building materials, environment, energy and chemistry. It is thought that examining the studies in this way will be a guide to fill the existing gaps in the literature and lead to development.

Keywords: *Tea factory waste, agriculture and livestock, energy, environment*

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1. INTRODUCTION

Traditional fossil fuels, which are used more than renewable energy sources in the world, are non-renewable resources with the potential to be depleted. In addition, it is known that non-renewable resources cause great harm to human health and the environment, such as global warming, climate change and harmful emissions[1]. Renewable energy sources promise a more liveable future and hope by minimizing these damages. One of the renewable energy sources with a very high potential is biomass energy. Biomass energy is a controllable energy that does not have interruption problems as in solar and wind energies[2].Biomass resources have the potential to be used in many different areas because they are clean, sustainable, diverse, easily available and inexpensive. Biomass consists of terrestrial, aquatic, domestic and industrial wastes. Energy from biomass sources is widely utilized as a heat source in industries such as forestry and paper industries, and for cooking and heating. In addition, biofuels obtained from biomass can be used in areas such as transportation and electricity generation. Besides its use as energy, biomass can also be utilized to obtain various high value-added chemicals[3, 4]. Figure 1 shows the conversion of biomass wastes into biochar and its use in various fields.

Figure 1. Converting organic waste into biochar and used in different areas (adapted from [5])

One of the sources of biomass is tea waste, which is formed from the fiber, stem and powder parts of tea leaves, which are released during the production of black tea in tea factories. The tea beverage is obtained by processing the leaves of the Camellia Sinensis plant. Black tea is consumed the most in the world. This is followed by green tea, oolong tea and white tea, respectively [6].White tea from unripe tea leaves, green tea without fermentation, oolong tea by semi-fermented and black tea by full fermentation is produced [7]. In our world, where two-thirds of the population consumes tea, tea consumption increased by 4.5 percent from 2007 to 2016, reaching approximately 5.5 million tons (Fig. 2) [8].

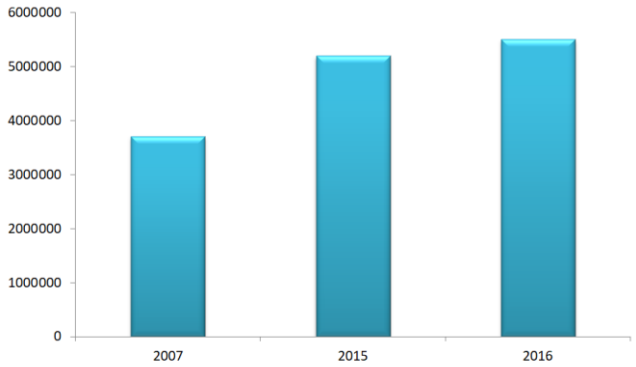

Figure 2. World tea consumption quantities

The tea plant, which is consumed intensively, grows in certain regions due to climate selectivity and it is desired that the factories be close to the raw material. This ensures that tea factory wastes are collectively formed at certain points and facilitates accessibility. In addition, the transportation of TFW does not involve great difficulties and facilities for its evaluation can be established at any point. Another factor that makes TFW worth using is that it occurs spontaneously in tea production processes and has no economic value.

Tea production consists of 5 main processes. These are withering, rolling, fermentation, drying and sorting packaging. Withering is a process for lowering the moisture content of tea leaves. The process of spreading the cell sap to the surface by curling the leaves in the rolling machines takes place in the rolling unit. Then, the fermentation process is started in the presence of moist hot steam in the fermentation unit. When the tea has the desired taste, smell and color, it is dried in the ovens in the drying unit. Finally, the tea is separated from the unwanted fiber, stem and powder parts in its content with various steps and categorized and packed in big bags[9]. Figure 3 shows the process of separating fibers from tea. In Figure 4, there is an image of the tea factory wastes.

Figure 3. Fiber receiving system

Figure 4. Tea factory waste

The content of tea and tea waste varies depending on factors such as the region where it is grown, the harvest period and the production method. In a study, two different production methods are discussed and mineral substance values are examined according to different parameters. The effect of production methods on the amount of mineral matter is shown in Figure 5 [10]. In general, TFW has a high C content of around 50% and an O content of 41%. It also contains H, N and S elements. TFW is a lignocellulosic biomass source containing lignin, cellulose and hemicellulose together [11]. TFW is rich in C, Cl, N and K however poor in P. Tea waste has a C/N ratio of 26 and a pH of 5.3 [12].

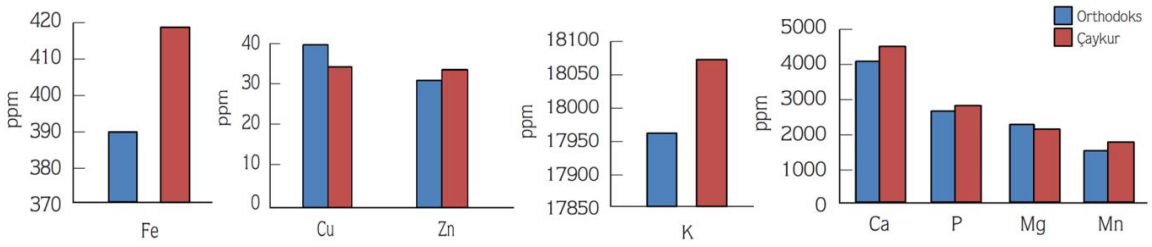

Figure 6. Tea content change according to the production methods (adapted from [10])

Each element in its content creates a potential for the utilization of tea factory wastes in different areas. In this study, the areas where tea factory wastes, which are a biomass source, are used were compiled and grouped under 5 main headings. These are agriculture and livestock, environment, energy, building materials and chemistry.In this way, it has been presented to the attention of researchers with examples in which areas and in what ways the wastes of the tea factory are used. It is aimed that this study will shed light on filling the gaps in the literature and generating new ideas.

2. AGRICULTURE AND LIVESTOCK

Chemical fertilizers have been used for many years to meet the nutritional needs of cultivated plants. However, excessive and unilateral use of these fertilizers causes some environmental problems. For this reason, it has become necessary to use organic fertilizers more effectively in agriculture[13]. In traditional agricultural systems, the decrease in the amount of organic matter in the soil causes two important problems as the sustainability of the soil and the decrease in production efficiency. In the case of insufficient organic matter coverage, the development of plants grown in agricultural lands and the activity of living creatures using the soil as a habitat are significantly limited. Along with the protection of soil fertility, sustainability is largely possible by adding sufficient amount of organic material to the soil [14]. Barnyard manure is the most important and most used organic waste material source. However, recent studies have shown that many vegetable waste can also be a good source of organic matter [15].

Re-utilization of lignocellulosic wastes in various areas will increase the efficiency of the relevant enterprises and prevent environmental pollution caused by these residues. It is rich in polymeric structures carbohydrates such as cellulose, hemicellulose and lignin. Biotechnological applications offer unique options for the preservation of natural balance in the evaluation of waste. It is possible to combine lignocellulosicwastes with various methods and evaluate them as organic fertilizers in agricultural areas and forest nurseries [16]. The benefits of tea waste to the soil come from some of the elements in it.

One ton of the tea waste contains on average 25 kg pure nitrogen, 3 kg phosphorus and 40 kg potassium. The nitrogenous organic substance in the soil is broken down by microorganisms and turned into a useful form for plants. Phosphorus for plants; It is an important nutrient element for root development, maturation of the plant and increasing resistance against diseases. The rate of potassium in the soil affects the structure of the soil, organic matter, lime and pH.

The tea compost;

- It increases the water holding capacity of the soil.
- It increases the amount of nutrients in the soil.
- Regulates the relationship between plant nutrients in the soil.
- It increases the temperature of the soil.
- It increases soil organisms and microbiological activity.
- It provides aeration of soil.
- It reduces the dependence of soil on chemical fertilizers [17].

In a study carried out, tea waste from tea factories was mixed with fresh goat manure, dry clover and water. According to the data obtained, it was concluded that tea litter compost can be formed in a short time and used in agriculture. It is seen that this compost is especially important in terms of turning the nutrients in the tea into the tea plant [18]. Table 1 shows the studies using three different mushroom species. The general opinion is that tea wastes can be used in this area.

Table 1. Effect of TFW on mushroom species yield

Mushroom Plant	Result	References
Pleurotus eryngii (DC. ex Fr.) Quel.	It was concluded that the tea waste can be used in P. eryngii cultivation.	[19]
Agaricus bisporus (L.) Sing	When tea waste is evaluated in mushroom cultivation, it is possible to obtain both a product rich in protein and the use of waste compost as fertilizer.	[20]
Ganoderma lucidum	It was observed that the effect of substrates prepared with oak sawdust and tea production wastes on mushroom yield was positive.	[21]

The positive effects of tea waste compost on the development of green onion, pepper (capsicum annuum), spinach (Spinaciaoleracea L.), lettuce (Lactucasativa L.), fenugreek (TrigonellaFoenumGraecum), corn (Zea mays L.) and begonia (Begonia eliator 'Toran') plants root, leaf, wet and dry weights, fruit weight, plant height, nitrogen (N) and potassium (K) contents have been identified. Figure 7 shows the effect of 0 to 8% tea waste compost on pepper plant growth. It was determined that the growth of the plant accelerated as the dosage of the mixture compost obtained from TFW increased[22-27].

Figure 7. The effect of the same amount of salt dosage and increasing level of tea litter compost applications on the plant height of pepper (adapted from [22])

Since there are some harmful factors for animals in tea waste, it has been determined that these wastes should be used in animal nutrition in a limited way. There is about 6.3% tannic acid in tea wastes that prevents protein

metabolism. Therefore, it is not possible to use it as animal feed. However, a method has been developed: After tea wastes are left in chlorine-free water diluted 1/50 at night, the product obtained is purified from tannic acid without any change in the protein content. So this product can be made available as chicken feed [12]. The effects of tea wastes used instead of oat crop as roughage on live weight gain, roughage consumption, digestion degree of total ration dry matter and wool quality were investigated. As a result, tea wastes with a crude protein content of around 12-14% should be used in animal feeding in a limited manner [28].

When the studies were evaluated, it was determined that good yield was obtained as a result of the use of tea factory wastes as a mixture material in agriculture, however its use as a nutrient in animal husbandry was not very efficient. On the other hand, it is possible to evaluatesuccessfully the content of TFW in these areas by making it more useful.

3. BUILDING MATERIALS

Governments are setting new protective standards in the construction industry as human and environmental health awareness comes to the forefront with increasing demand on the community side. Therefore, natural resources are studied for important alternative materials to synthetic based and harmful dyes. One of these sources is tea waste. Tea waste can be used as coloring material. Besides the advantages of the wood material used in construction, it has to be treated with some preservatives and colorants in order to be protected against external influences and to be aesthetic[29]. Tea wastes can be applied for the purpose of obtaining and developing natural and water-based wood preservatives (dyes) and colorants that are harmless to the environment and human health by obtaining extracts from the natural product of tea [30].

It is possible to use tea wastes in different structures in the construction area. One of these is briquette production from tea waste. Cold-hardened composite briquette, which is the first stage of the process of producing iron metal from iron-based ore and wastes by blending with tea waste, was produced. The best results were obtained by drying the briquettes produced by adding CMC (Sodium carboxymethyl cellulose) up to 3% of the total material for 120 minutes at 200ºC [31]. In another study, the use of treated waste tea ash instead of cement in pavement blocks at 10%, 20%, 30%, 40% and 60% dosages was investigated. Replacing the cement with waste tea ash has reduced the quality of the paving blocks. However, it has met the minimum requirements set for some areas of use. The replacement of waste tea ash to cement has led to the production of a more sustainable and cost-effective paving block (Fig.9).This study is noteworthy as it is aimed at evaluating the secondary waste generated by the incineration of TFW. In this case, two-fold gain is obtained. TFW can be evaluated in two different areas and new waste generation is prevented. In another study, the usability of tea wastes as a natural fiber in concrete was investigated. As a result, it was concluded that tea waste can be used as natural fiber up to 7 kg in 1 m^3 of concrete, however it would be appropriate to use up to 5 kg in places that will be exposed to abrasion[32, 33].

Figure 8. Processed waste tea ash and fresh blocks (adapted from [32])

The usage potential of tea wastes in paper production, which is another building material apart from the construction sector, has been examined. It has been concluded that if the tea factory wastes are used in pulp production, it will contribute significantly to the raw material supply problem [34].In another study, it is concluded that tea wastes have taken place in the production of composite plates by determining some properties of particle board produced using tea waste by experimental methods and modelling of the results with fuzzy logic method was investigated. In addition, it has been tested efficiently in line with the analyses applied on the plates produced[35]. Figure 9shows the example of particle plate produced using tea waste and red pine.

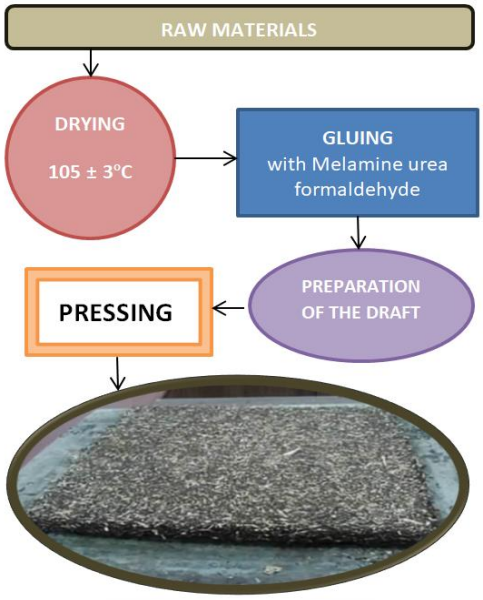

Figure 9. Hot pressed plate draft (adapted from [36])

In the use of TFW in the field of building materials, examples of paint, briquette, concrete, paper and particle board are encountered. In addition, it is seen that ash, which is the secondary waste formed after TFW is burned to obtain energy, can also be evaluated.

4. ENVIRONMENT

Although there are many methods such as evaporation, chemical precipitation and oxidation in wastewater treatment, one of the most used applications is adsorption. Adsorption is the process of passing the contaminant from the liquid product to the solid adsorbent [37].Large amounts of water are used in industry. Industrial wastewater contains pollutants that are harmful to the environment and health, such as toxic substances, heavy metals and inorganic substances. Cleaning of industrial wastewater is essential

both from an environmental and economic point of view. In addition, the increase in the world sea trade volume with each passing year has led to the increase in the dimensions of the tanker accidents that may occur in oil transportation, and thus the pollution dimensions. The magnitude of environmental impact caused by oil pollution caused by a tanker accident, the difficulty of cleaning activities and the high cost are clearly seen from past accidents [38, 39]. The use of organic biomass sources in wastewater treatment helps reduce carbon emissions and contributes to reducing the cost of wastewater treatment [40].

Activated carbons (AC) are adsorbents with high surface area and porous structure with high performance adsorption potential. In recent years, the production of activated carbon using biomass resources has become widespread due to its cheapness and effectiveness. TFW lignin can be used in the production of activated carbon due to its cellulose and hemicellulose properties as well as its high carbon content. As a result, it was determined that activated carbon produced with KOH (potassium hydroxide) showed higher performance in Methylene Blue adsorption, activated carbon produced with $ZnCl_2$(zinc chloride) in phenol adsorption and activated carbon produced with H_2SO_4(sulfuric acid) in adsorption of metals [41]. Figure 10 shows an activated carbon production reactor.

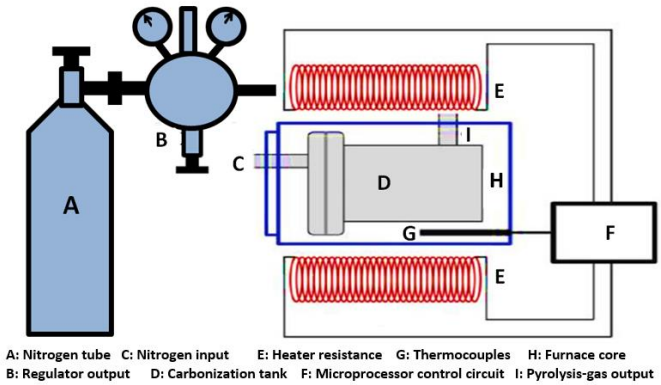

Figure 10. AC production reactor (adapted from [42])

In another study, activated carbon was produced from a mixture of tea waste-H_3PO_4(phosphoric acid) with an activation method including microwave pretreatment and carbonization. Methylene blue and phenol adsorption were investigated to determine the adsorption capacity of activated carbon produced from tea waste under optimal process conditions. Due to the high surface area and mesopore content of tea waste, it has been determined that it can be used as an adsorbent in the removal of organic substances that cause pollution in water [43]. Figure 11 shows the stages of preparing activated carbon with microwave pretreatment and impregnation using H_3PO_4 and K_2CO_3 (potassium carbonate).

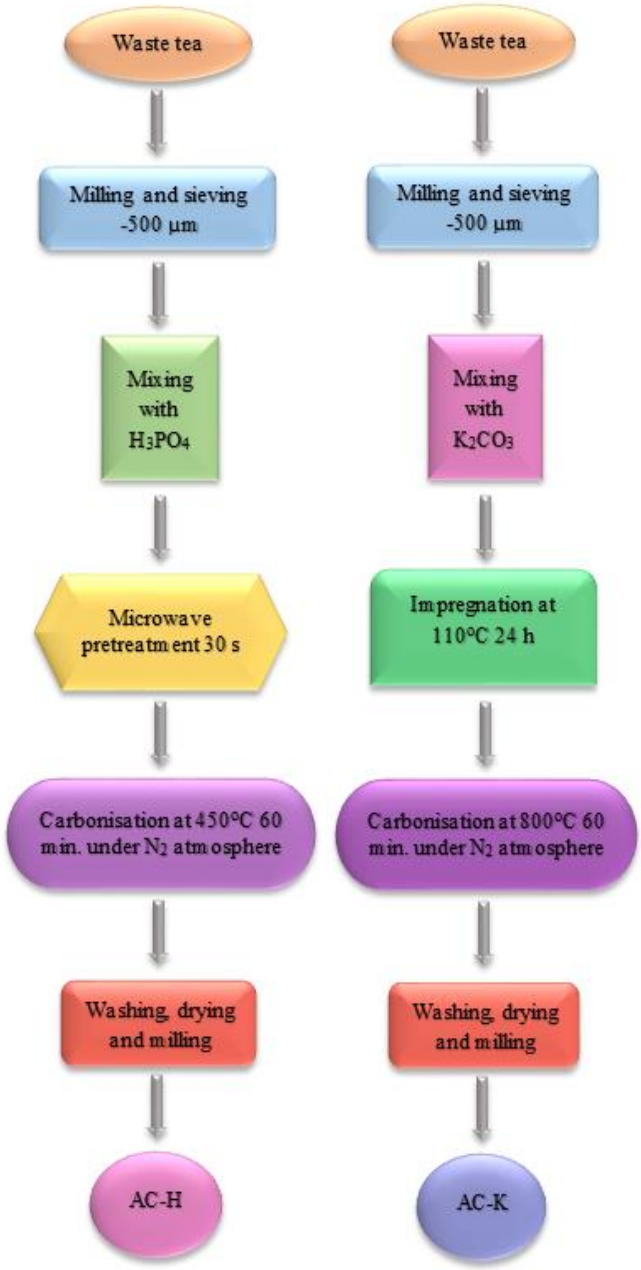

Figure 11. The schematic illustration of the production processes of the activated carbon samples (adapted from [44])

In another study, tea factory wastes were used as biosorbent material for the removal of Pb(II) from synthetic wastewater. The maximum Pb(II) removal capacity of TFW was found to be 22,111 mg g^{-1} at 200 mg L^{-1}[45].Biochar is a substance that can be used for various purposes. In a study, biochar was prepared from TFW with five different carbonization methods and the prepared biochar was used for the adsorption of tetracycline from the water medium. It has been observed that carbonization methods have different effects on the properties of biochar. It has been determined that $KHCO_3$ (potassium bicarbonate)-biochar has the maximum adsorption capacity[46].In another study, TFW biosorbent was used for Cu (II) and Zn (II) adsorption. Zinc showed higher adsorption efficiency compared to copper[47].

AC and biocharproduction with different materials and methods to be used in wastewater treatment from a cheap and environmentally friendly biomass source such as TFW shows very efficient results.

5. ENERGY

Energy sources used in the world are generally grouped in two main groups. These are non-renewable or conventional energy sources are also known as fossil fuels (oil, coal and natural gas) and renewable energy sources (solar energy, biomass energy, geothermal energy, wind energy, wave energy, hydrogen energy, etc.). The ever-increasing world population also increases the demand for energy. As a result, concern that the limited resources of fossil fuels will quickly decrease and be exhausted and toxic and poor quality wastes from high quality energy need cause major environmental problems forced scientists to conduct research on new energy sources [48]. In this regard, biomass resources are a very good alternative because they provide continuity and are a cheap and environmentally friendly renewable resource.

In a study, biochar was derived from tea factory waste and grape seed resulting from the processing of tea and grapes, and the usability of the obtained biochar as a solid acidic catalyst in the production of biodiesel from waste cooking oil was investigated. As a result, it has been determined that it is functional to convert tea wastes and grape seeds into carbon catalysts with high added value instead of inefficient burning or leaving them to decompose in nature[49].Such studies show that versatile and functional products that can be used not only for a single purpose but also in different fields can be produced from TFW.In Figure 12, an example of biochar production by pyrolysis from tea waste and the use of biochar in energy storage is shown schematically.

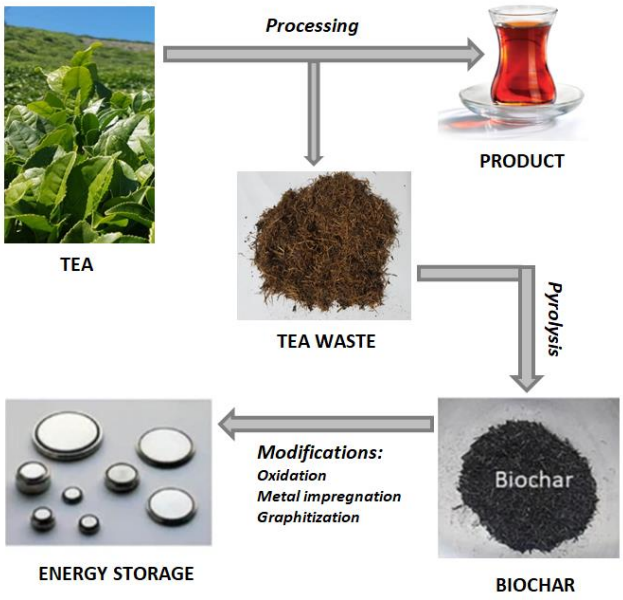

Figure 12. Use of tea waste biochar for energy storage (adapted from [50])

Another form of TFW that can be used in energy storage is its use as electrode material in supercapacitor design. In a study, a hybrid electrode consisting of TFW-based activated carbon and graphene was produced. The capacitance of the hybrid electrode, which was subjected to various processes to increase the electrochemical performance, was measured as 110 F/g[51].In another study, the catalyst produced from TFW using NaOH was used both as an electrode material in supercapacitor design and as a catalyst in hydrogen production experiments. The results were found promising. In this study, TFW appears to be quite functional[52].

During active carbon production from tea waste, it can be obtained in other chemical products. For example, tea waste can be subjected to pyrolysis. Pyrolysis is the oldest and simplest method to obtain gas from biomass, and it is the thermal decomposition process that occurs by heating organic materials in an oxygen-free environment. As a result of pyrolysis, substances such as gases, tar, organic compounds, water and charcoal are obtained[53].

In another study, three different biomass sources, including tea waste, were subjected to pyrolysis with and without catalyst, and the yield of liquid product was investigated. It was observed that the structural properties of the biomass and the catalyst used affect the liquid product yield [54]. It is also possible to obtain gaseous energy from TFW. In a study on this subject, gasification reactions of tea waste were carried out in an upstream tubular reactor in air and air+steam medium in order to produce a hydrogen-rich gas mixture. The activities of the catalysts were investigated in the gasification reactions of tea waste. It was observed that the liquid products obtained were rich in phenolic compounds and caffeine, and there was not much change in the structure of the solid products [55].

An example of solid energy production from tea factory waste is pellets. According to the data obtained as a result of pellet biofuel production from TFW, it has been determined that the use of tea waste as pellets is suitable both in terms of fuel properties and environmental factors [56]. In another study, it was observed that the materials were pelleted with high quality without using any adhesive and the tea pellets were in a solid structure as a result of physical tests [57].

Bioenergy and biofuel in solid, liquid and gas form can be obtained from tea factory wastes. These are valuable products with a wide range of uses. However, studies on the use of TFW in the field of energy can be increased.

6. CHEMISTRY

Tea leaf is a rich resource of polyphenols, especially catechins. Depending on the region where it is grown, the amount of catechin in green tea can reach up to 30% of the dry weight of the leaf. Catechins are of interest because they are very beneficial for human health. The catechin found in tea is also useful for the food industry [58].Tea factory wastes also contain caffeine and catechin, and it is possible to obtain them by different methods. Caffeine production from tea waste consists of three main processes. The first of these is to expose tea wastes to solid-liquid extraction with hot water. The aqueous extract obtained here is subjected to liquid extraction in the second stage with a solvent that can dissolve caffeine well, such as chloroform. The final stage consists of solvent recovery and classification of raw caffeine [59].

In a study, caffeine and catechin amounts, extraction and analysis methods of wet tea, caffeine powder and black tea waste were investigated. Wet tea samples were found to

contain higher amounts of catechin than waste, in accordance with the literature, however black tea waste and caffeine powder also contained significant amounts of catechin. It was determined that the most efficient method was hot water extraction[60]. In another study, the extraction of caffeine and catechin from the same samples by microwave method was investigated. In the samplings conducted in 2013-2014, it was determined that the samples showed significant differences according to the years without a standard catechin and caffeine content and the seasonal conditions [61]. In a study in which caffeine was extracted from tea waste by the supercritical carbon dioxide extraction method, it was concluded that it would be possible to obtain approximately 5 times the caffeine need of Turkey when a process that can produce caffeine by only evaluating TFW is established [62]. The flow chart of the supercritical extraction setup is shown in Figure 13.

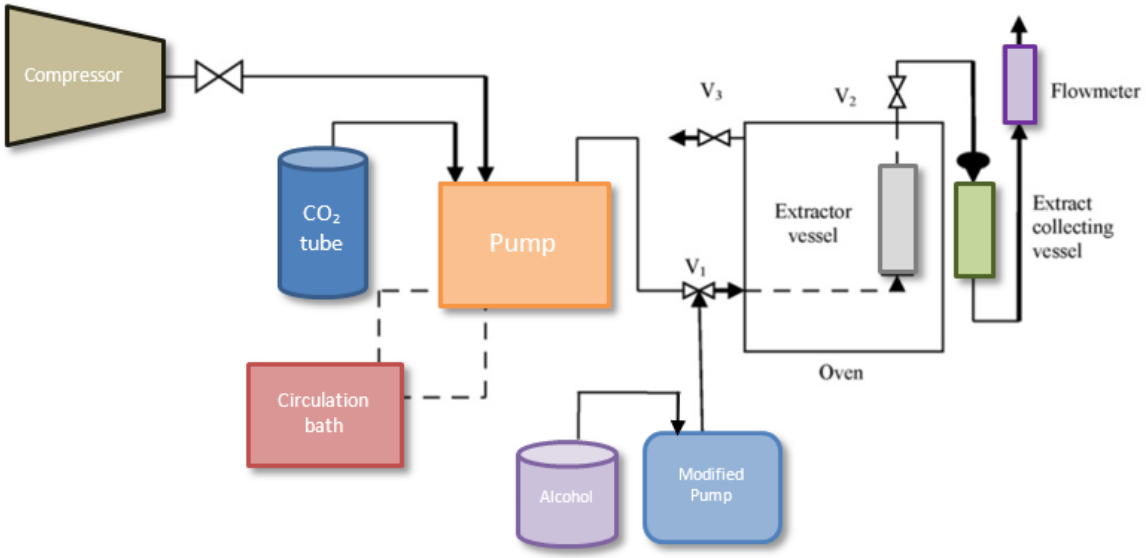

Figure 13. Flow diagram of the supercritical extraction set-up (adapted from [63])

One of the most important areas of study recently has been on antioxidants, which play a role in cleaning free radicals that cause many diseases such as cancer, atherosclerosis, cataracts, Parkinson's disease and aging. Antioxidants are defined as molecules that delay, clean or prevent the oxidation of their molecules against oxidative damage. Antioxidant mechanisms are present in the organism as protective against pro-oxidant substances. These remove harmful oxidants or repair damage caused by the reactive oxygen species in vivo [64]. Studies on the antioxidant efficiency of tea wastes have been conducted. Phenolic components of tea and its wastes were examined and the effects of tea samples on enzymatic activity were measured by measuring antioxidant enzyme activity in the erythrocyte cell model. As a result, it has been determined that tea and wastes have antioxidant capacity and also green tea and its leaf waste have higher antioxidant effect than black tea [65].

Another study aimed to determine the phenolic content of extracts from black and green tea and their different wastes and to compare their protective effects against oxidative DNA damage induced by hydrogen peroxide in human lymphocytes by single cell gel electrophoresis (comet) method. As a result, it has been determined that tea wastes are as effective as tea itself and can make an economic contribution by evaluating it in terms of its protection against DNA damage [66].In another different study, it was aimed to develop a new method to increase the extract rate of Turkish tea. Optimum conditions were determined to obtain suitable extract from tea waste. As a result of the processes, the extract rate of the tea was increased from approximately 29% to 32% and no negativity was found in the tasting tests[67].

It is seen that tea factory wastes are evaluated in different ways in the field of chemistry. The work appears to be promising, at the same time open to enrichment.

7. CONCLUSION

The world is in search of resources to meet the needs of the increasing population. In this case, it is wise to make wastes that have no economic value available. In this study, the evaluation methods of tea factory wastes, which are released in large quantities and collectively, in different areas were investigated.Studies are grouped under five headings: agriculture and animal husbandry, building materials, environment, energy and chemistry[68].The aim of the study is to show that a biomass resource can be used in different ways and to give new ideas to researchers.The results of the study are listed below.

It is seen that tea factory wastes are used in the development of different types of plants such as pepper, spinach, fenugreek, mushroom species, lettuce in agriculture. It has been determined that TFW can be used as a compost material thanks to the nutrients it contains. The effect of TFW can be observed by diversifying plant species. Then, the efficiency can be increased by using it in greenhouses and it contributes to the economy.

It has been determined that TFW should be used in a limited way in animal husbandry. However, a method such as soaking in 1/50 diluted chlorine-free water has been developed and the harmful substance for animals has been removed [12]. Such new methods can be developed. Its effects on the development of animals and its use in farms can be investigated.

In the field of TFW building material, it has been used to make paint, briquettes, paving stones, concrete, paper and particle board. In some studies, it has been determined that it has sufficient performance and in others it is at a level that can be improved. The use of products such as newspapers, packaging, ornaments and insulation materials can also be investigated. Since no new waste will be generated in its use as a building material, the damage to the environment is reduced to zero.

It has been used as a biosorbent in the production of multifunctional products such as TFW activated carbon, biochar and in the treatment of wastewater.

The works have been enriched by using different materials and methods. It is seen that TFW can be used successfully in this field. It is seen that different efficiencies are obtained for different pollutants. Comparisons can be made by diversifying the studies.

TFW has been used in the energy field in the production of solid, liquid and gas biofuels and energy storage. These are biodiesel, biochar, hydrogen, pellet production and supercapacitor design. It is promising that TFW can be evaluated in this way in various forms. However, energy is a very broad field and is open to development.

In the field of chemistry, TFW has been used in the production of caffeine and catechin by different methods and in the production of antioxidants that play a role in curing various diseases. There are also different studies where it is evaluated as a protective against DNA damage and as an extract enhancer. The fact that a waste material with no economic value can be made useful in different ways will shed light on new studies.

As can be seen, tea factory waste, which is a biomass source, can be used in different areas thanks to its rich content. Studies in these areas can be diversified, and the use of TFW in different areas such as food, clothing, etc. can be investigated. In addition, studies can be developed by using different materials and methods in studies with insufficient efficiency.

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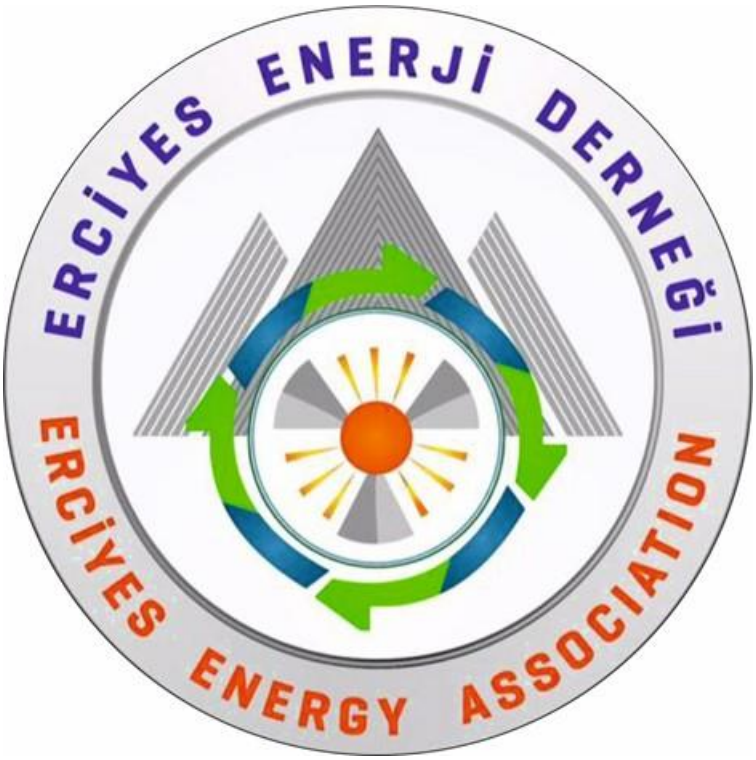

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