An-Najah National University

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Graduation Project (2)

Evaluation of the use of pyrolysis technology for used car dash panel and environmental improvement in Palestine

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ABSTRACT

Palestine is completely dependent on the occupation as a source of energy due to the political conditions and the geographical area of the lack of oil resources and the complete control of the occupier over any source from which it can produce energy. Recently, Palestine has turned to alternative energy sources such as solar energy or recycled energy, which achieve two important goals for optimal use of energy and environment-friendliness instead of total dependence on fossil fuels, as energy is one of the most expensive commodities in Palestine compared to neighboring regions. The pyrolysis process has been studied for several materials such as (acrylonitrile butadiene styrene, polyethylene, polypropylene, and polyvinyl chloride). Scrap cars in Palestine the market shows that this part is disposed of in wrong ways and is harmful to the environment such as direct burning in the atmosphere which leads to an increase in harmful emissions into the atmosphere. Through this study, it was found that these materials are very rich in oil resulting from the pyrolysis process of the dash panel that was cut and samples were taken from two companies x and y, where two samples from the company x contain the first (x1) polyvinyl chloride, and the second (x2) polypropylene with threads and the sample of y company contains polypropylene was burned without the presence of oxygen, which gave good quantities of oil produced from the process, produced through pyrolysis of a sample of y company and produced oil by (75%) and solid by (21.17%) and produced the x2 sample by percentage (68%) and solid (15.31%). As for the x1 sample, the results were different. When pyrolysis was done, a very black gas was produced that did not condense and solid product (14.33%).

Table of Contents

LIST OF TABLES

LIST OF Figures

List of Abbreviations:

ABS	Acrylonitrile butadiene styrene
PE	Polyethylene
PP	Polypropylene
PVC	Polyvinyl chloride
HDPE	High-density polyethylene
LDPE	Low-density polyethylene
PMMA	Polymethyl methacrylate
YZ	Yttria Zirconia
EWC	Embedded Wireless Controller
NZ	Natural zeolite
FCC	Fluid Catalytic Cracking
ZSM-5	Zeolite Socony Mobil-5
HZSM-5	High Zeolite Socony Mobil-5
MFI	Mobil Finite
USY	Ultrastable Y molecular sieve
HBeta	High Beta
HUSY	High Ultrastable Y molecular sieve
RON	Octane number
FT-IR	Fourier transform infrared
ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

One of the most important sources of power for any country is the extent of its possession of energy because it is the most important pillar of development and industry, specifically in Palestine energy is one of the most expensive commodities and this affects the development of the country in several areas, the most important of which is the industry [1]. And this problem has several reasons, the most important of which is the country’s dependence on the only source of energy, which is the occupation, due to the siege imposed on Palestine by the occupier to limit the development of Palestine and to completely control energy, especially fossil energy [2]. Not only in Palestine but the whole world, and one of the most important ways to use energy is recycling because of its great benefits to the environment and energy alike, as it gets rid of a good amount of materials that are no longer have used to reproduce new energy in ways that are good for the environment [3].

Some of the car parts that have gone out of service are spread in Palestine these parts are considered a major source of pollution to the environment due to the wrong method used to dispose of these parts, such as direct burning of these parts in the air while getting rid of these parts through the pyrolysis process will be an environmentally friendly method[4] [5].

This study is based on recycling the car dash panel into materials that can be used in the field of energy through pyrolysis [6]. There is a large share in Palestine of the centers where this part is collected.

Composite materials: materials made by combining two or more different materials, their basic components having different properties where the compound presents completely new materials with new and different properties, and the goal of this material is to improve the thermal, chemical, mechanical properties or some other physical properties [7].

The global need for high-performance, economical and high-quality products has drawn the attention of researchers in the field of composite materials [8] [9], so the focus has been on the selection of composite materials in the automotive industry, but historically high oil prices in recent years have led to an increase in demand on solutions for cars characterized by low fuel consumption [8].

The use of composite materials in the industry leads to an improvement in mechanical properties, thus increasing the strength and durability of the final product [8] [9], and improving dynamic performance due to the lower weight of the composite material compared to the material composed of a single material. The use of composite materials enhances environmental friendliness by reducing exhaust emissions. The car and several other reasons [8].

Pyrolysis is a two-syllabic Greek word: the first syllable **pyro** (fire), and the second syllable **lysis** (separation). Scientifically, it is a process of thermal deterioration through which cracking takes place in the primary bonds of substances in an oxygen-free atmosphere [10].

The process aims to recover materials in the form of carbon products or petroleum raw, and gases similar to natural gas, where these products can be used and upgraded to high-value products and fuels as well so that this process is environmentally friendly and works to protect them from waste materials whose combustion in the atmosphere leads to the production toxic gases harmful to the environment and humans usually the products that come out of this process are divided into three parts are gaseous part consisting of hydrogen, methane, and carbon oxides, a liquid part consisting of water, tar, and oils (organic compounds), and solid residue containing fixed carbon (coal) and oxides (metals, oxygen) and these outputs depend on several factors, including temperature, heating rate, pressure, time and the composition of the burned material [11].

CHAPTER 2

LITERATURE REVIEW

There is a great trend in the world toward recycling waste that is a cause of environmental pollution due to the wrong methods used to dispose of this waste, and one of the most important of these processes is pyrolysis, this table (1) summarizes previous studies of pyrolysis for four types of materials (ABS, PE, PP, and PVC) and shows the effect of using a catalyst in some pyrolysis processes and its effect on the process results.

Table 1: **summarizes previous studies of pyrolysis for three types of materials(ABS, PE, PP, and PVC)**

Author year	Operation temperature (℃)	Catalyst	Objective	Result	Reference
Eniko Szabo , Marton Olah et al 2011	420	-	Study of the pyrolysis of waste (ABS-PMMA) to determine the products of the process, examine them, and compare them with the fuel products	This process produced a large amount of liquid by 65% and it was shown that the interaction between (ABS-PMMA) reduces the temperature required for the decomposition of ABS from 420℃ to 370℃. Density, pressure, and octane number (110.2) were determined, and it is preferable not to use them in cars directly	[12]
Mihai Brebu , Thallada Bhaskar et al 2004	450	Yes Fe-C Ca-C	Pyrolysis study of high-density polyethylene or polystyrene and ABS-Br polymer mixtures with the use of a catalyst to determine the percentage of gas and oil produced from this process	The use of a catalyst containing Fe in this process removes bromine from the produced oil and reduces the catalyst from nitrogen. The study showed that the percentage of the produced oil was 71% and the percentage of gas was 10-14%, in the presence of PS \ ABS. Also, this oil can be used as fuel oil or materials Primary in the oil refinery	[13]
Chinnathan Areeprasert , Chanoknunt Khaobang 2018	500	YES YZ(Fe/YZ), Fe/ZSM-5, Fe/BC and Fe/EWC	Study of the amount of oil and gas produced from the pyrolysis process of ABS / PC with the presence of iron oxide catalysts	The catalysts were an important reason for producing a good amount of oil, and the study showed that the percentage of oil ranges between 40%-75% when using the catalyst.	[14]
Su-Hwa Jung, Seon-Jin Kim, Joo-Sik Kim 2013	474 525	-	This study aimed to produce OIL from high-impact polystyrene (HIPS) and acrylonitrile. butadiene–styrene (ABS) by pyrolysis process with temperature change from 474℃ to 525℃	It was noted that the amount of oil at a temperature of 474◦C is greater (87%), while the amount of oil at a temperature of 525℃ (84%), this oil is not used as fuel directly, that is, it must be treated	[15]
vangelia C. Vouvoudi, Aristea T. Rousi, Dimitris S. Achilias 2017	320	-	This study aimed to recycle some of the waste plastic parts found in electrical and electronic devices (ABS, HIPS, PC) and convert them into energy through the pyrolysis process and examine the products.	The study showed that the pyrolysis process is effective for recycling this waste and that the products can be used as fuel after treatment.	[16]
An-Ke DU, Qian Zhou et al 2011	372.5	-	Study of the pyrolysis of (ABS) without nitrogen at atmospheric pressure	It was found that ABS without nitrogen increases the proportion of oil, so the	[17]

				result of the process was 73.6% oil and 15% gas.	
Grzegorz Gałko , Michał Rejdak et al 2021	600	1- without a catalyst 2 - ZSM-5 catalyst possessing ammonium groups 3- ZSM-5 catalyst containing 10 % Ni	Study of the amount of oil produced from the pyrolysis process of ABS with and without the use of a catalyst	The study showed that the amount of oil produced from pyrolysis without catalyst was 52%, while the amount of oil was 73% with the presence of ZSM-5 catalyst possessing ammonium groups and 85% with the presence of ZSM-5 catalyst containing 10% Ni	[18]
Takaaki Wajima, Zar Zar Hlaing, Akiko Saito et al 2015	450	-	Conducting the pyrolysis process of Br-ABS with flame retardants and NaOH at a temperature of 450 ◦C and studying the changes in the quantities of the products	An increase in the amount of oil produced was observed from 56% to 63%, while gas increased from 4% to 8%, and the solid waste increased from 27% to 34%	[19]
Marcin Sajdak 2017	600	-	Study of the pyrolysis process of ABS, PP, SBR, and PET with woody or agricultural biomass and its effect on the number of products	Adding biomass increases the proportion of oil and gas in the pyrolysis process, where the proportion of oil increased from 31.5% to 38.1%, while gas increased from 15% to 22%	[20]

Ranbir Bagri, Paul T.Williams et al 2002	500	Y-Zeolite ZSM-5	Studying the effect of a zeolite catalyst on the gases produced by the pyrolysis process of polyethylene.	The result of the process without catalyst was 95% oil, 2.5% gas, and 2.5% coal. With a catalyst of 85% oil, 10% gas, and 5% coal, the proportion of gas increased with the presence of the catalyst.	[21]
Jude A. Onwudili, Nagi Insura et al 2009	300-500	-	The work of pyrolysis of polyethylene (LDPE) Study of the effect of temperature on the proportion of the resulting oil.	The temperature had an effect on the percentage of oil produced at a temperature of 350℃, the percentage was 97%, and with an increase in it, the percentage decreased as a result of its transformation into gas and coal, at temperatures of 425℃ and above, and it was found that the decrease in the density of polyethylene leads to less oil, and more gas and coal.	[22]
Valerio Cozzani 1997	500-800	-	Study of how coke is formed in the pyrolysis process of polyethylene (LDPE) and its comparison with diesel soot used in the production of coke.	It was found that there are tar-cracking reactions that play an important role in the formation of coke, and the percentage of its formation at a temperature of 500℃ is 2.8% and at 800℃ is 24.1%. It was found that the resulting coke is similar to the diesel soot used in its production.	[23]
Chantal Kassargy,	450	(USY) zeolite	Carrying out the pyrolysis of	The liquid yield was high, the coke deposits were low at 450 °C, and the	[24]

Saru Awad et al 2017			polyethylene with a catalyst, making a separation of the liquid product, and comparing it with gasoline and diesel.	liquid was separated at 170 °C. The proportion of gasoline-like fuel was 60.6% and diesel-like fuel 35.3%, and the octane numbers of gasoline-like (RON=97, RON=96).	
Zezhou Chen, Xurui Zhang et al 2020	500-600	HZSM-5	Study of the pyrolysis of polyethylene with a catalyst (HZSM-5) at different temperatures and the effect of these conditions on oil production.	The percentage of oil at a temperature of 600°C was 68%, and at 500 °C was 89%. A decrease in the temperature has a high oil yield.	[25]

Sachin Kumar, R.K Singh 2011	400-500	-	Recovery of liquid from the pyrolysis process of (HDPE).	At a temperature of 450°C, the product was a liquid of 23.8% and a viscous liquid or a waxy solid of 50.8% at 475°C, the components of the resulting liquid were analyzed, and a mixture of different fuel parts appeared such as gasoline, kerosene, and diesel.	[26]
J. Zeaiter 2014	550	HBeat HUSY	Making pyrolysis of polyethylene with two types of zeolite catalysts and examining their effect on the amount of gas produced.	Gas production in the absence of a catalyst reached 17.8%, and in the presence of catalysts, a percentage ranged between 93-95%. The presence of catalysts affected the increase in the percentage of gas produced, reaching 90% or more.	[27]
N. Kiran, E. Ekinci et al 2000	439	-	Recovery of hydrocarbons and petrochemicals for power generation through the pyrolysis of waste polyethylene and polystyrene plastics.	Polyethylene produced 37% liquid and gas by 35-45%, and polystyrene produced 63% liquid and 20% gas.	[28]
F.J Mastral, E. Esperanza 2002	650-850	-	Making pyrolysis of HDPE at different temperatures and checking the percentage of products that come out of this process.	At a temperature of 650°C, the main production was a waxy substance with a percentage ranging between 68.5-79.7% and a gas rate of between 11.4-31.5%, and the production of gas increased at high temperatures and the best 780°C by 68.4% gas and 9 6% oil.	[29]
Leilei Cheng, Jing Gu et al 2020	340	-	Examination of the effect of pressure (1-50 bar) on polyethylene pyrolysis products.	High pressure led to the transformation of polyethylene into liquid and gaseous products. Gas increases and liquid decreases with high pressure. At low-pressure conditions, the liquid percentage ranged between 26.77-37.3%, and with high pressure, the liquid percentage reached 15-20.24 %, which makes the characteristics of the product close to the fuel.	[30]

J.L.YE Q. Cao et al 2008	550	-	Co-pyrolysis procedure between polypropylene and 50% biomass and 50% polypropylene and 50% biomass.	The temperature was 550°C which was suitable for decomposition and when the temperature was raised to 600°C and the products were gases by 30% and liquid by 20% and the rest are solids.	[31]
Y.B Sonwane Mahsen Shindikar et al 2015	450	NZ	Study Pyrolysis of polypropylene waste with and without catalyst.	The process without catalyst lasted 90 minutes and its presence was 65 minutes, and the process without catalyst resulted in 80.82% of liquid fuel and with 10% the catalyst, the ratio reached 86.4%.	[32]
Mehrdad Abadi, Mehdi Haghighi et al 2014	450	Fcc	Production of fuel-like hydrocarbons by pyrolysis of polypropylene and determination of the effect of parameters from temperature and catalyst.	The heat cracks the polypropylene and the catalyst improves the economic viability of hydrocarbon production. At a temperature of 450°C and 10% of the catalyst is the maximum production of hydrocarbons.	[33]
Young-Min Kim, Hyung Lee et al 2017	500	HZSM-5 MFI	Co-pyrolysis of polypropylene and biomass with two types of catalysts.	From this process, 60.5% liquid was produced, and the resulting liquid was very close to fuel.	[34]
Elena Zanella, Micol Della Zassa et al 2013	360-420	-	Study of the combined pyrolysis of polypropylene and coffee waste and the effect of temperature.	Polypropylene does not degrade at 360°C while coffee waste decomposes easily and yields 25.6% liquid. Upon reaching a temperature of 420°C, a liquid with higher viscosity of up to 71.7% is produced. This combined process allows the production of a liquid comparable to fossil fuel oil.	[35]
Imtiaz Ahmad, M.Ismail Khan 2014	250-400	-	Study of the pyrolysis of polypropylene and HDPE.	At a temperature of 350°C, the total percentage of HDPE products is 98.12%, while polypropylene at a temperature of 400°C is 98.66%, and when analyzing the liquid products and comparing them with characteristics, it was found that they are similar to fuel and conform to fuel standards.	[36]
Chaney Park, Jechan Lee 2021	800	-	Study of the pyrolysis of three weight particles of polypropylene (PP 12, PP250, and PP340) and the effect of weight on the production of chemicals used in fuels.	Gaseous polypropylene products consist of methane, ethane, ethylene, propylene, and propane, and at a temperature of 800°C degrees, the three types of hydrocarbons were similar to gasoline, jet fuel, diesel, and engine oil, PP250 and PP340 produced ratios higher than PP12, where the percentage was in PP250 (37.7% gasoline, 38.6% jet fuel, 7% diesel and 3% hydrocarbons used in motor oil).	[37]
M. Martyins Mulyazmi et al 2019	250-400	-	Study of the pyrolysis of 1 kg of polypropylene at different temperatures.	The process at 400°C achieved a maximum yield of 88.86 percent of liquid fuels, which can be compared to commercial fuels, and their viscosity and calorific value were close to kerosene and their density close to that of gasoline.	[38]

Chantal Kassargy, Saru Awad et al 2017	450	(USY) zeolite	Carrying out the pyrolysis of polypropylene with a catalyst, making a separation of the liquid product, and comparing it with gasoline and diesel.	The liquid yield was high, the coke deposits were low at 450 °C, and the liquid was separated at 170 °C. The proportion of gasoline-like fuel was 57% and diesel-like fuel 36.5%, and the octane numbers of gasoline-like (RON=97, RON=96).	[24]
George Kofi Parku, Francois-Xavier Collard et al 2020	450-600	-	Comparison of pyrolysis products of polypropylene under different atmospheric pressures and temperatures with fuel products.	The best results appeared at temperatures 488 and 525°C, and the proportion of the products was 46% liquid and 40% gas when compared with fuel products, it was found that they are similar to gasoline.	[39]
Kim-Bum Park et al 2018	400	-	The pyrolysis of LDPE waste and PVC - Plasticized waste was carried out at a temperature of 400°C.	This process resulted in liquid, solid and gaseous components, and the proportion of these components was 55% gas, 42% liquid, and 3% solid.	[40]
Wenchao Ma et al 2019	500	-	The pyrolysis of PVC and organic materials such as sawdust was carried out at a temperature of 500 °C.	The co-pyrolysis process results in liquid and gaseous components, where the proportion of liquid was 45% and gas was 55%.	[41]
Puyou Jia Meng et al 2015	460	-	The co-pyrolysis process of PVC, soybean oil, and phosphate was carried out at 460°C.	The results of this process were distributed between liquid and gaseous materials, where the proportion of gas was 50% and the proportion of liquid was 40%.	[42]
Junbo zhou et al 2016	350	-	The process of pyrolysis of PVC wires with other plastic waste was carried out at a temperature of 350°C.	This process resulted in 51% liquid and 47% gas.	[43]
Puyou Jia et al 2015	325	-	Pyrolysis of PVC was carried out with materials containing soybean oil at a temperature of 325°C.	The resulting components of the combined pyrolysis process were 36% gas and 48% liquid.	[44]

After summarizing table (1), which studies the quantities of oil and gas production from the pyrolysis process of (ABS, PE, PP, and PVC) materials, in particular, it is clear that these materials are very rich in energy and can be used as fuel, but after processing the products, and based on those studies, pyrolysis will be done for the Dash Panel, which is expected to contain it. On these materials, which are one of the most important parts of cars that are destroyed incorrectly and harmful to the environment in Palestine in particular, some catalysts can be added to the process to help extract the largest possible amount of oil.

CHAPTER 3

METHODOLOGY

3.1 Problem Identification

Conventional fossil fuels in Palestine are limited and expensive due to the scarcity of supplies and political conditions. The energy industry in the Palestinian territories is also under occupation control, Palestine also suffers from the presence of a good amount of car parts, the number of scrap car collection centers in Palestine is 569 in 2020 [45]. And each center has about 200 cars annually, which cause a source of air pollution due to harmful emissions to the environment resulting from the wrong way to dispose of it, such as direct burning in the air. The primary goal is to develop an efficient alternative energy source to improve energy stability, which will obtain good energy under the high price of energy in Palestine using pyrolysis.

3.2 Materials

The material used in this project is the dash panel, which is found inside cars and consists of polypropylene and PVC ،polypropylene is a thermoplastic resulting from the polymerization of propylene and is used in many applications, including the automotive industry and consumer product packaging[46]. In terms of PVC, it is another type of thermoplastics and it comes in third place in production after polypropylene and polyethylene. It differs from other thermoplastics in two ways the first has wide physical and mechanical properties and the second its microstructure depends on the processing conditions[47].

3.3 Methods

Using a simple model of the pyrolysis device to study the pyrolysis process of the dash panel, it was built in one of the laboratories of the department of chemical engineering at an-najah national university using simple tools, where the flask represents the reactor and a glass tube that transfers the decomposition products from the reactor to another glass tube that works on the principle of a heat exchanger to condense the gas produced from the reactor, and the resulting oil is collected in a glass beaker, and the heat source is located through a gas cylinder that is ignited to heat the reactor as shown in figure (1).

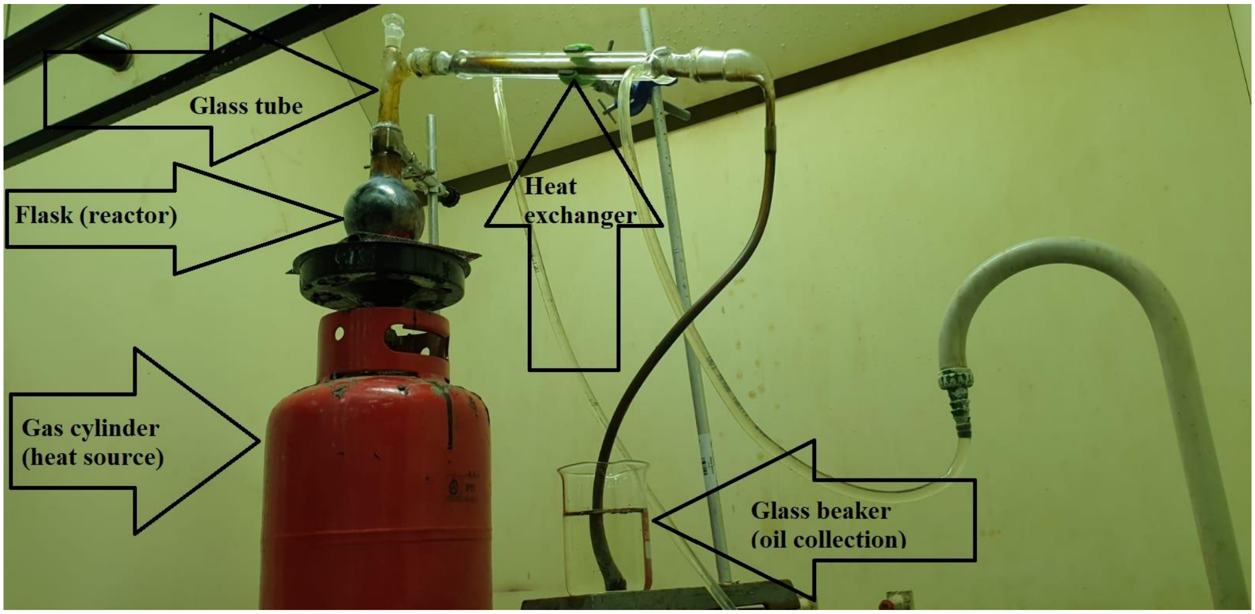

Figure 1 :**Pyrolysis device setup model**.

Working on three types of samples, two of them are from x company and a sample from y company, where the first sample consists of x company made of pvc and the second sample was made of polypropylene with some threads and the y company sample consisted of pure polypropylene, ten grams of each sample were known the samples were placed in the reactor and the flame was ignited below to work on heating the reactor, which resulted in the decomposition of the samples from solid to liquid, then gas, it moves from the reactor to the first tube connected directly to it, then moves to the heat exchanger, which works to convert gas into oil, which is collected in a glass beaker, and the solid products were collected the remaining in the reactor which will be illustrated in the results chapter.

CHAPTER 4

RESULTS

4.1 Operation temperature of pyrolysis

By studying the literature reviews that performed the pyrolysis process for four materials (ABS, PE, PP, and PVC) and showed the quantities of oil and gas produced from the process, whether by adding catalysts for the reaction or without, at several temperatures ranging from 320-800 and the average of these degrees was 450 which It gave good results[24].

4.2 Quantities of scrap cars in Palestine

After studying the Palestinian market, it was found that it possesses a large share of scrap collection centers and thus provides a large number of car dash panels, which are usually sold by burning. The following Table (2) shows the number of scrap sales centers by governorates.

The following Table (2) shows Statistics on the number of "scrap car collection centers" in Palestine in 2020[45].

Table 2: Statistics of the number of "scrap car collection centers" in Palestine (2020)[45].

Governorate	The number of scrap sales centers
Jenin	68
Tubas	5
Tulkarm	29
Nablus	148
Qalqilya	31
Salfit	5
Ramallah and Al-Bireh	127
Jericho and Valley	3

Bethlehem	55
Hebron	98
Total	569

4.3 Composite material pyrolysis oil

The results of the literature reviews showed that the pyrolysis process is effective for producing good quantities of oil and gas[18].

The catalyst had a major role in increasing the production of oil and gas in the pyrolysis process, as the results of the oil were about 65% without a catalyst[12]. But with the use of the catalyst, the percentage increased to more than 71%, in the pyrolysis of ABS[13].

As for PE, it gave greater amounts of ABS, which was estimated at more than 90% oil, while without catalyst, it was much less[27]. It differed from one study to another according to the process conditions of the temperature and type of polyethylene, whether it was high or low density, as it was found that HDPE gives more oil[36].

When performing the pyrolysis process of polypropylene, the results were a little different from the above, but it gave good amounts of oil, as the oil production rate was approximately 80%[32].

While the products of the pyrolysis process of PVC mixed with several materials separately such as soybean oil, biomass had different proportions as the gas ratios were very high compared to the rest of the products of other materials[41].

FT-IR acquisition was carried out for the three polymer samples by Thermo Scientific Nicolet IS5 FTIR device equipped with ATR sampling apparatus in the range of 4000–650 cm1 with 8 cm1 resolution and 64 scans[48].

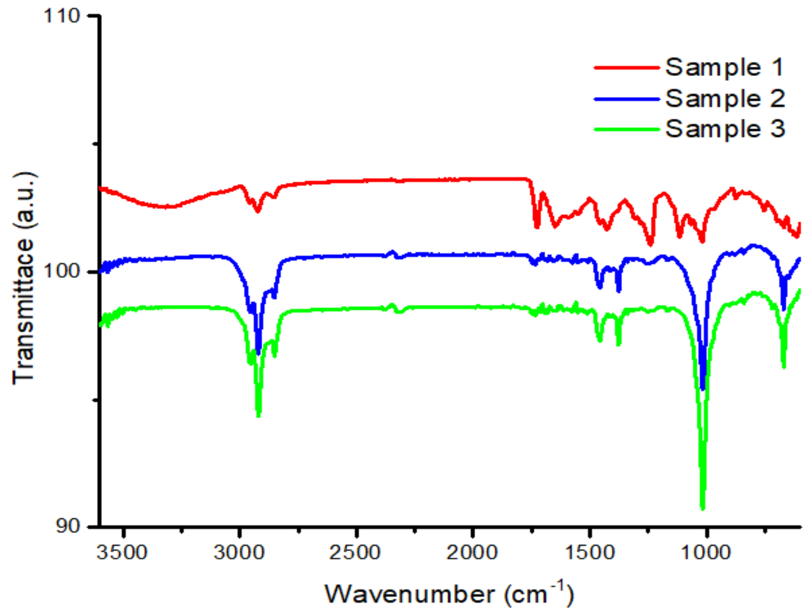

Figure 2: data of FT-IR test to 3-samples.

The FT-IR spectrum of sample 1 shows different peaks at 3330, 2917, 1728, 1649, 1422, 1235, 1114, 1008, and a fingerprint between 800 and 600 cm-1 which could indicate that the tested sample is plasticized PVC and that also would be clear from the leather texture of the sample[49].

On the other hand, samples 2 and 3 demonstrate similar peaks at 2950, 2920, 2853, 1464, 1380, and 1015 cm-1 with a slight difference in the intensity of 1015 cm-1 (C-O-C) in sample 3 which could be attributed to the slight oxidation or certain contamination of the surface of the sample. Herein and according to FT-IR spectra, both samples could be considered polypropylene[50].

Samples were taken from the dash panel of two different types of cars (x,y). After examining the FTIR test procedure for those samples, it was found that the sample taken from x contained two polypropylene materials with the symbol x2 and PVC symbolized by x1. In contrast, the sample is taken from the x2, and y turned out to contain polypropylene, after which pyrolysis was experimentally carried out.

The experimental results of the pyrolysis process for the x2 sample were rich in oil, knowing that no catalyst was used in the process, as the percentage of solid was much lower than the oil. The results of the x1 sample were completely different from the rest of the results, as there was difficulty in condensing the gas into oil, and therefore the results were only gas and solid and the ratio of the solid was not high but was almost similar to the x2.

As for the experimental results of the pyrolysis process for the y sample, it gave good quantities of oil and the amount was less than a quarter of the outputs, while the gas percentage was very small, knowing that the quantities of oil in this sample were the highest compared to the rest of the samples.

Table (3) below shows the quantities of the experimental pyrolysis process products and the products for the literature reviews.

Table 3:**Results of the experimental pyrolysis process and the results of literature reviews**.

Product / Sample	Oil	Solid	Gas
	experiment		
X2	68%	15.31%	16.69%
X1	-	14.33%	85.67%
y	75%	21.17%	3.83%
	Literature reviews		
PP[32]	80%	-	-
PE[27]	90%	-	-
ABS[12]	60-70%	-	-
PVC[40]	40-50%	-	45-55%

Based on the results shown in Table (3), it is noticeable that the results of the literature reviews and the experimental ratios are close to each other, where the experimental ratios were slightly less than the literature reviews. The dash panel contains good amounts of oil, it was true.

There were problems that had a role in the difference between the experimental results and the results of the literature reviews, including the inaccuracy of the device used in the pyrolysis process and the lack of a device to control the heat source, as well as the presence of a gas leak that affected the amount of oil produced and the element used for condensation was not with the required efficiency to work on condensing the largest amount of gas to produce oil.

4.4 Economic feasibility

Through the statistics of the ministry of transport and communications, it was found that Palestine has about 569 centers for collecting scrap cars[45]. at a rate of 200 cars annually in each center, and based on this statistic. In the pyrolysis experiments conducted for the dash panel, 10 g of the dash panel produces approximately 0.007 liters of oil and the researchers estimated the weight of the dash panel as about 10 kg. By comparing the quantities and their equation, the entire dash panel produces approximately 7 liters of oil, and through the existing statistics on the number of cars. The number of the dash panel was estimated at 113800 and its mass was 1138000 kg based on the experiment and the equation of results the oil output was estimated at 796600 liter/year.

4.5 Analysis of samples produced by pyrolysis

The pyrolysis of polypropylene was done and the physical properties of the oil produced from the process were compared with gasoline and diesel fuels to determine the quality of the oil produced from the pyrolysis and to know the extent of its affinity with the existing fuels[38].

Table 4:**Comparison of the physical properties of gasoline, diesel fuel, and polypropylene oil** [38]**.**

Fuel/Parameter	Density $\frac{Kg}{m^3}$	Kinematic viscosity $\frac{mm^2}{s}$	Calorific Value $\frac{MJ}{s}$
polypropylene oil	796.9	1.5398	44.95
Gasoline (RON 88)	715-780	-	44.56
Diesel Fuel	815-860	2-4.5	42.8
Testing method (ASTM)	D 1259	D 445	D 240

CHAPTER 5

CONCLUSION

The pyrolysis process is proven to be highly efficient in producing waste oil and an effective means of recycling, helping to dispose of the vehicle's dash panel while minimizing damage to the environment from those in use such as a burn. It is possible to benefit from the results of pyrolysis of the materials that make up the dash panel (PVC, PP) as fuel after treatment, as shown by the FTIR test that was conducted on a sample of the dash panel and showed that these materials are present in the composition of the car dash panel.

Where the (PP) products were close to the calorific value of gasoline (RON 88) and diesel, based on a test conducted for oil produced from the pyrolysis process of PP.

It was found that the PVC sample decreased the proportion of oil produced and coal and gas increased significantly. The x2 sample gave good results in the quantities of oil, but less than the quantities of oil produced by the y sample, and these results were very close to the results of literary reviews. After the experimental results, it can be concluded that the dash panel contains good quantities of oil that allow achieving good results and the success of the process, whether on the environmental level or on the profit level, even without using any catalyst for the reaction, in addition to that this process does not require complicated and expensive machines and thus finding source energy is important in light of the shortage of energy resources in Palestine and the total dependence on the occupation for energy while achieving the goal of environmental friendliness due to the availability of large quantities of this waste.

It is possible to predict a good future for this work and its sustainability for a long time, in addition to solving the problem of environmental pollution resulting from the wrong disposal of this waste, and a good financial return can be expected due to the good quantities of oil resulting from the pyrolysis process. There are several problems that reduce the return on profit such as the high cost of labor in Palestine, the occupation, high taxes, and some other problems such as the limited use of output due to unwanted emissions.

And after these results, there were some recommendations and future plans, so there are some solutions to improve the results and increase the quantities of oil, thus increasing the efficiency of the process and achieving its goals better. One of these solutions is the use of devices that help control temperatures and isolate the device well and Its composition so that gas leakage is very little, in addition to the use of a larger and better heat exchanger until the gas is fully condensed, and a heat exchanger can be used through several stages, in addition to the possibility of using some reaction catalysts to help speed up the reaction and thus better results, and following those recommendations It is better to build a device that includes these conditions before starting any study related to the pyrolysis process, in addition to conducting tests for the oil produced before and after the treatment process and comparing the efficiency of the oil with diesel and gasoline in the experiment by studying the performance of the engine.

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