Converting Plastic Waste Into Pyrolysis Oil

Abdulhakim Alnasser(ME), Turki Alhajri(ME), Rayan Asiri(ISE), Hosam Alzahrani(CHE), Eid Alamiri(CHE)

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Introduction

Plastic waste is a growing environmental challenge, with traditional recycling unable to meet demand. Pyrolysis offers a promising solution by converting diverse plastic types into pyrolysis oil, a valuable fuel and feedstock. This project aims to design a simulated pyrolysis system for efficient plastic waste processing.

Problem Statement

The increasing accumulation of plastic waste poses significant environmental and resource management challenges, with traditional recycling methods proving inadequate to address the growing demand for sustainable solutions. To tackle this issue, there is a need for an efficient and adaptable system capable of converting diverse plastic waste into valuable products. The project aims to develop a simulated pyrolysis system that meets the following specifications: achieving a minimum conversion efficiency of 60% to produce pyrolysis oil, processing at least 20 tons of plastic waste per day, and accommodating at least three different types of plastics.

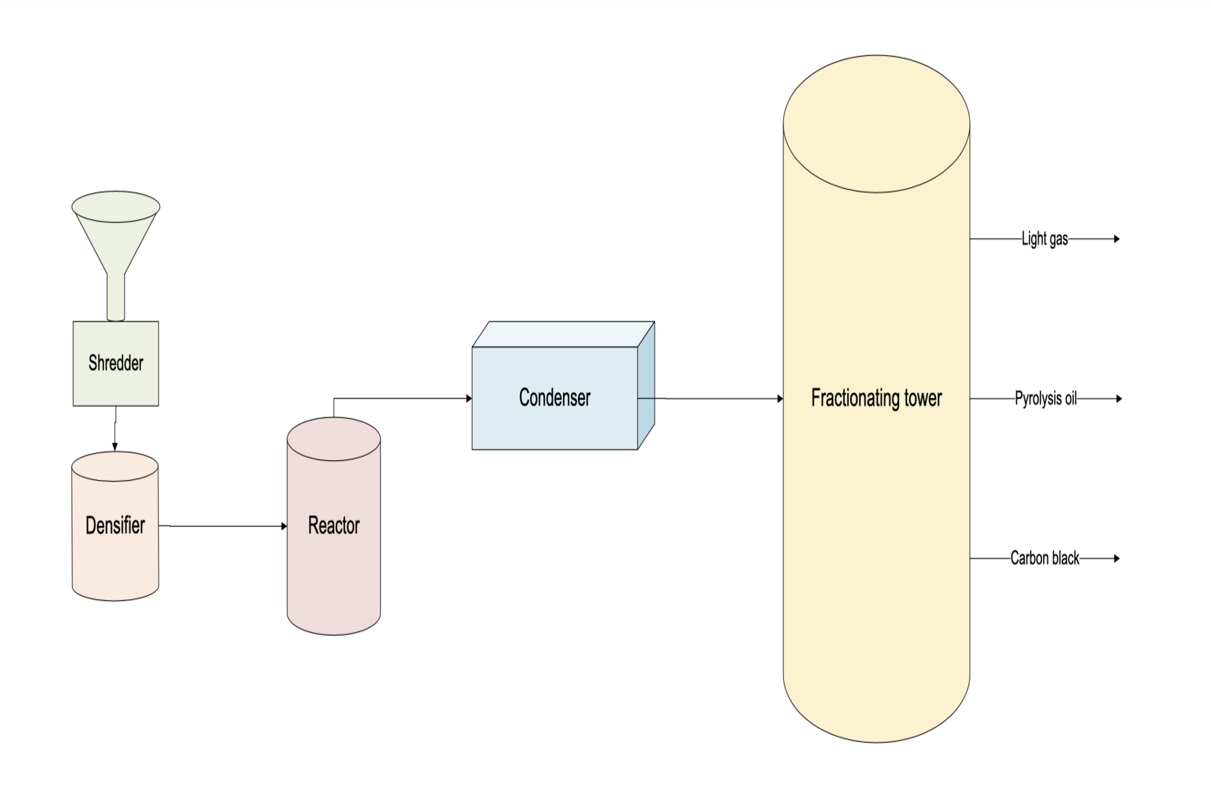
Pyrolysis Process

Pyrolysis is a thermochemical process conducted with little or no oxygen, transforming plastic waste into valuable products like pyrolysis oil, which serves as chemical feedstock. It offers a sustainable alternative to landfilling and incineration, addressing environmental challenges while enabling resource recovery.

Specifications	Result
Convert at least 60% of plastic waste into pyrolysis oil.	The result of the simulation shows that 65% of the plastic was converted into pyrolysis oil.
have a minimum of 20 tons of plastic waste per day.	The equipment dimensions, motor speeds, and optimal route model were calculated to ensure they could deliver over 20 tons per day.
be flexible enough to consume at least 3 different plastics.	three different types of plastic were used in the simulation HDPE, LDPE, and PP.

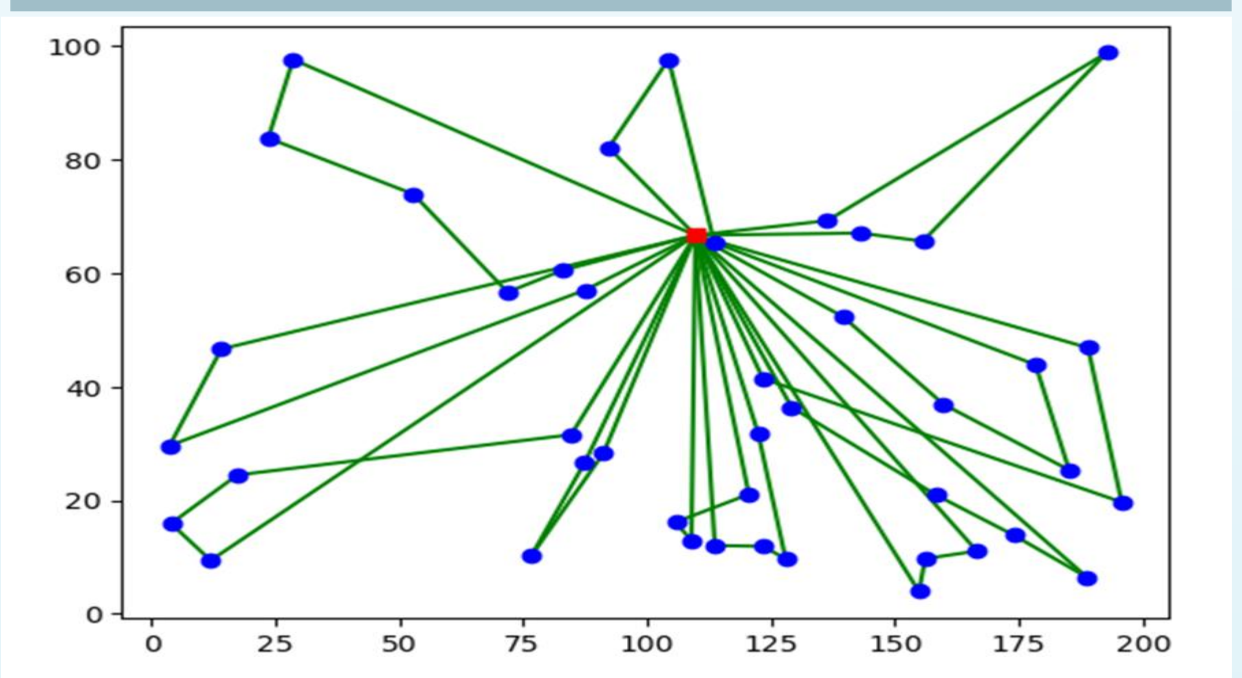
Constraints	Result
Residence time of plastic must be around 2 seconds.	The mass flow rate in the reactor pipe, which has a diameter of 1 inch, is 0.23 kg/s. Using the velocity equation, a specific pipe length was selected to ensure a residence time of 2 seconds.
Reactor material must be capable of withstanding temperatures of at least 525°C	Based on ASME codes, carbon steel A-106 was selected for the reactor, as it can withstand a temperature of 525°C and an allowable pressure of 3975 psi.
The number of vehicles to use in collecting plastic waste.	Create an optimal route using a mathematical model to collect over 20 tons of plastic waste with a limited number of vehicles.

Design Overview

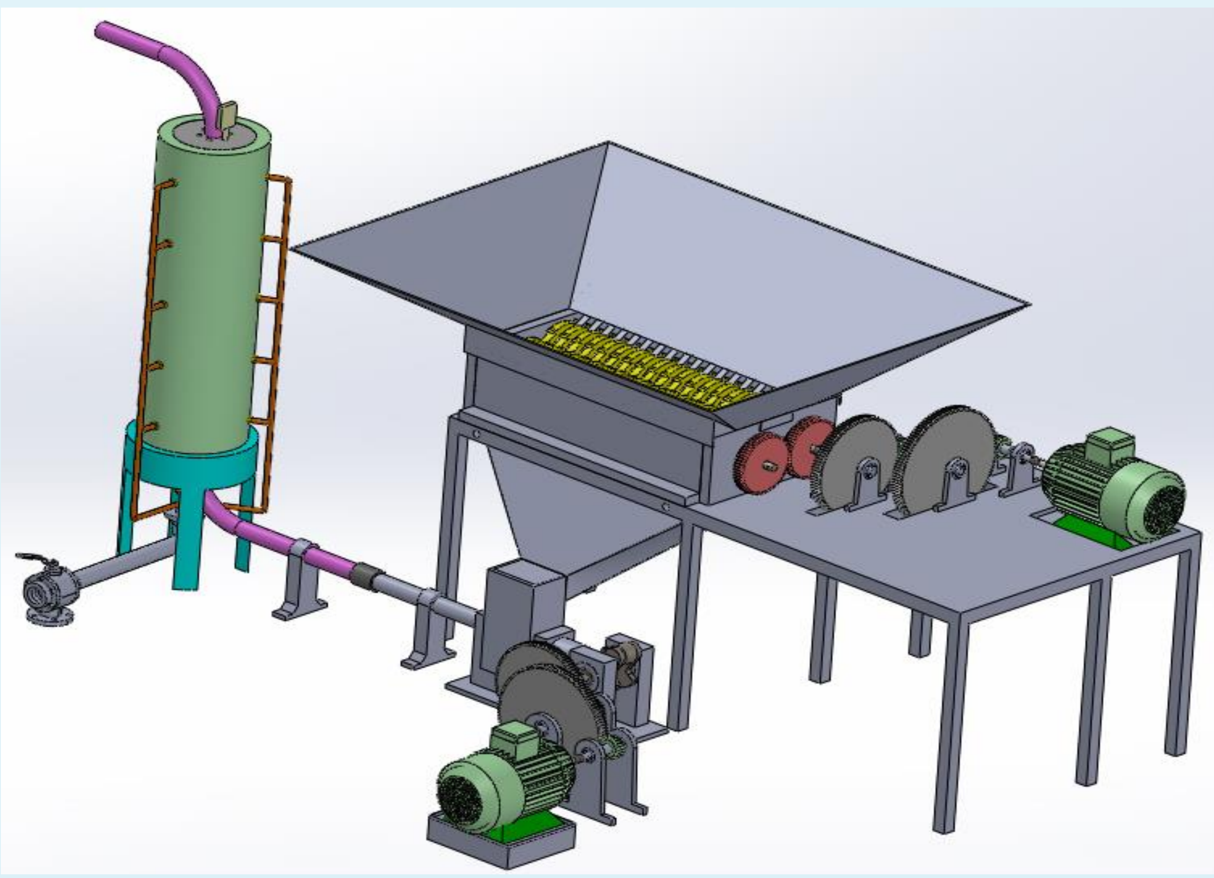


The plastic is first fed into a shredder equipped with cutting blades to break the plastic into smaller pieces. It is then transferred to a densifier, which uses a reciprocating piston to compress the plastic into a 1-inch diameter pipe, creating a low-oxygen environment before conveying it to the reactor. The reactor is the main component of the system and is equipped with heating burners to melt the plastic, converting it into a gaseous state at 525°C. Also, the reactor contains a catalyst which is used to speed up the chemical reaction. The gas coming from the reactor will enter a condenser, where it is converted into liquid form. Finally, the liquid passes through a fractionating tower, which separates the oil mixture into light gas, pyrolysis oil, and carbon black.

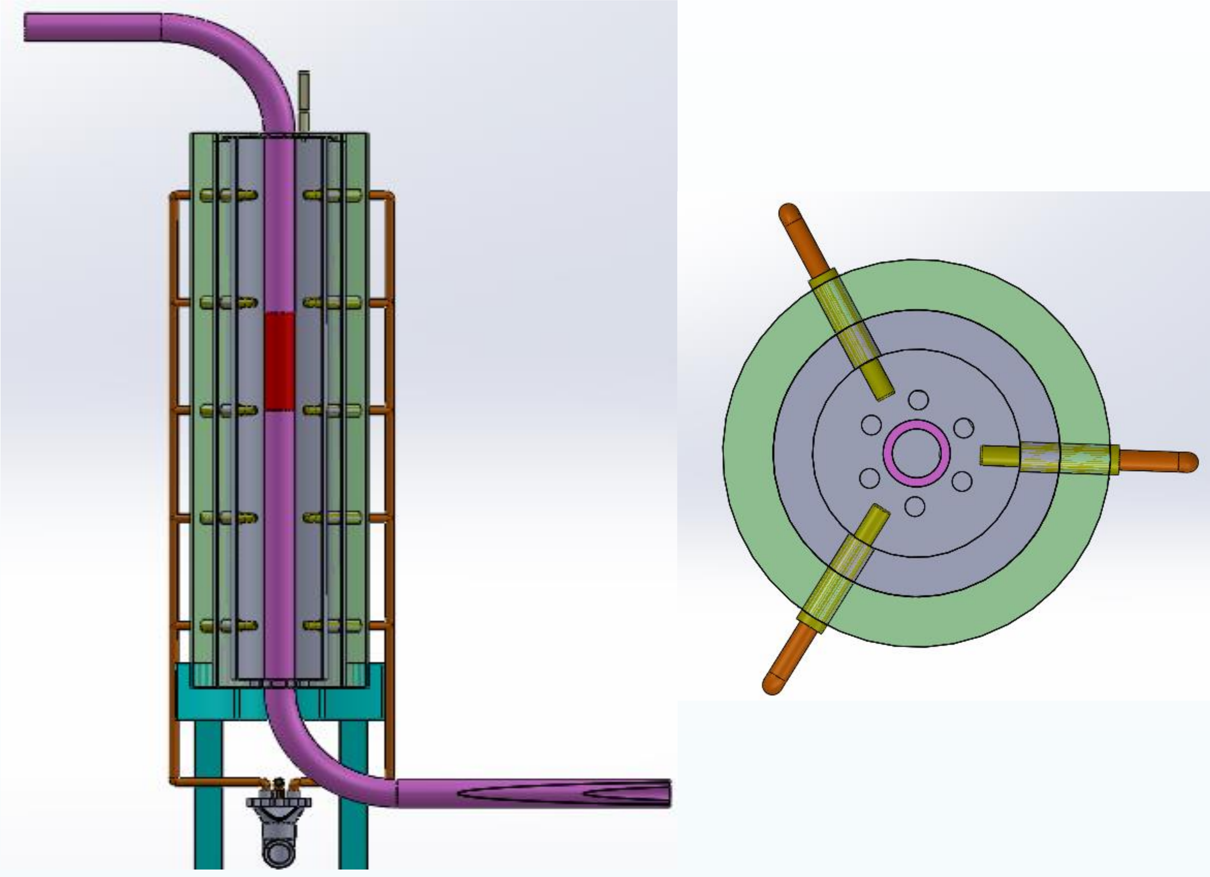
Optimizing Plastic Collection Process



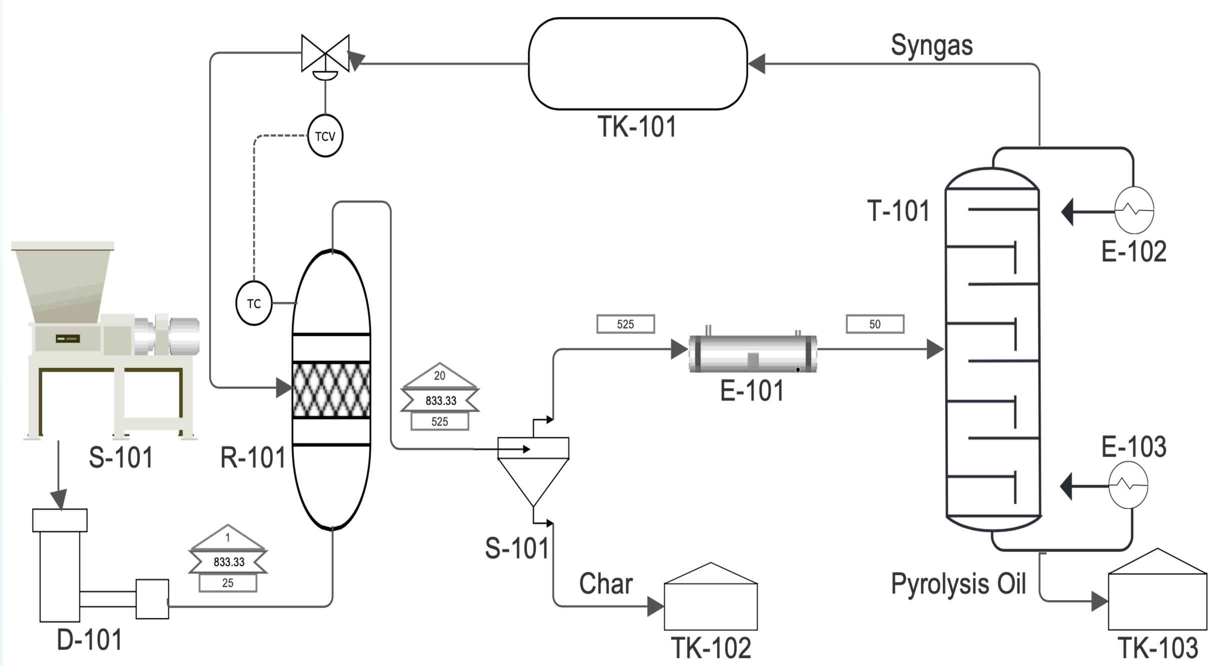
SOLIDWORKS Design



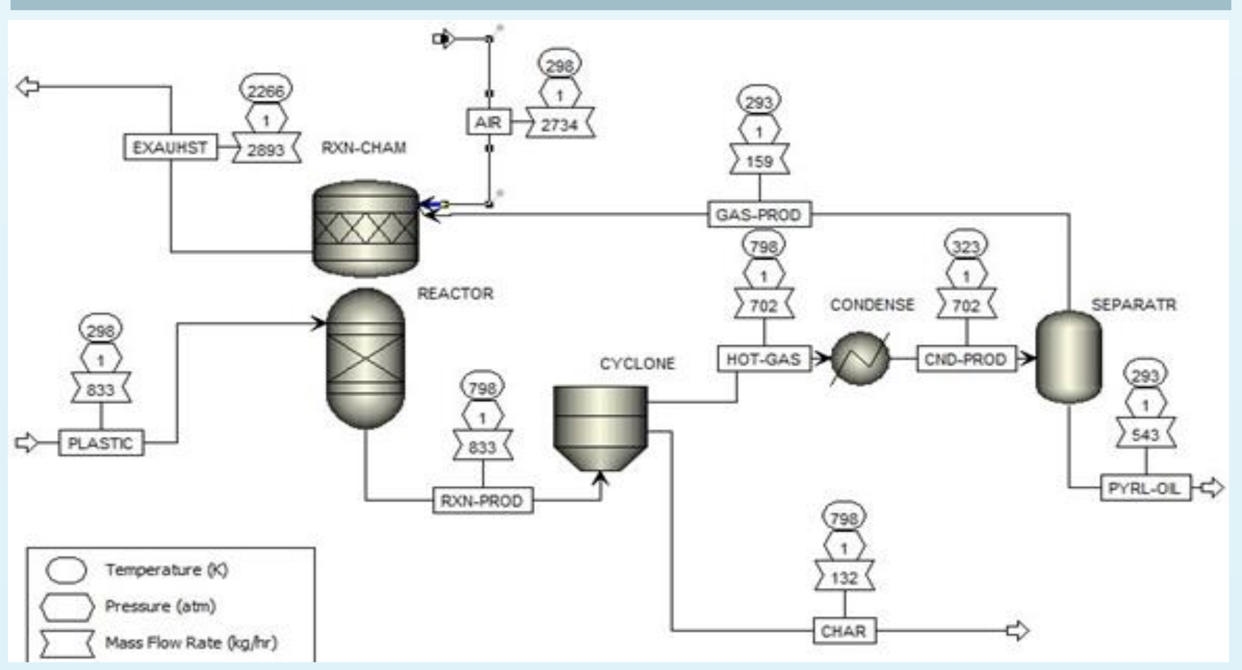
Reactor Section-Views



Process Flow Diagram



Simulation of the process on ASPEN PLUS



Theoretical mass balance

	MW (g/Mole)	Feed Mass Flow Rate (Kg/h)	Feed Mole Flow Rate (Mole/h)	HDPE Rxn coeff.	LDPE Rxn coeff.	PP Rxn coeff.	Product Mole Flow Rate (Mole/h)	Product Mass Flow Rate (Kg/h)
HDPE	28.0	333.33	11887.66	-36	0	0	0	0
LDPE	28.0	250	8915.83	0	-36	0	0	0
PP	42.1	250	5943.89	0	0	-29	0	0
H2	2.0	0	0	1	1	1	782.84	1.57
CH4	16.0	0	0	1	1	1	782.84	12.55
C2H6	30.1	0	0	1	1	1	782.84	23.52
C2H4	28.0	0	0	1	1	1	782.84	21.95
C3H6	42.1	0	0	1	1	1	782.84	32.93
C3H8	44.1	0	0	1	1	1	782.84	34.50
C4H10	58.1	0	0	1	1	1	782.84	45.47
C8H18	114.2	0	0	1	1	1	782.84	89.38
C16H34	226.3	0	0	1	1	1	782.84	177.18
C28H58	394.6	0	0	1	1	1	782.84	308.88
C	12.0	0	0	5	5	20	6988.61	83.93

Bill of Materials & Cost

SHREDDER

ITEM NO.	PART NAME	MATERIAL	QTY.	MASS (g)	MASS DENSITY (kg/m^3)	COST ($)	SOURCE
1	Frame	AISI 1020	1	122770.39	7900	184.16	-
2	Side Plate	AISI 1020	2	31624.95	7900	47.44	-
3	Bearing mounting plate	AISI 1020	2	13441.11	7900	20.16	-
4	Shaft	AISI 4340 Steel, normalized	2	36852.69	7850	165.84	-
5	Fixed Blade	AISI 1020	36	28787.01	7900	43.18	-
6	Spacer	AISI 1035 Steel (SS)	36	10376.60	7850	20.75	-
7	Cutting Blade	AISI 1035 Steel (SS)	36	22250.96	7850	44.50	-
8	Bottom hopper	AISI 304	1	6692.75	8000	20.08	-
9	Top hopper	AISI 304	1	32598.97	8000	97.80	-
10	Shaft-3	AISI 4340 Steel, normalized	1	194.51	7850	0.875	-
11	RushGears_2020_Z2M100	AISI 1045 Steel, cold drawn	1	4903.66	7850	15.69	-
12	RushGears_2020_Z2M20	AISI 1045 Steel, cold drawn	2	353.61	7850	1.132	-
13	Shaft-2	AISI 4340 Steel, normalized	1	242.13	7850	1.09	-
14	RushGears_2020_Z2M120	AISI 1045 Steel, cold drawn	1	7074.15	7850	22.64	-
15	Shaft-1	AISI 4340 Steel, normalized	1	148.64	7850	0.67	-
16	Motor assembly	-	1	-	-	1000	Alibaba
17	Coupling15	AISI 304	1	16.93	8000	0.05	-
18	Coupling12	AISI 304	1	13.92	8000	0.04	-
19	skf_bearing_1207_ektn9_2	-	4	-	-	224.96	MROSupply
20	Housing15	Grey Cast Iron	3	956.93	7200	1.15	-
21	Housing12	Grey Cast Iron	3	977.97	7200	1.174	-
22	skf_bearing_16002_2	-	3	-	-	59.01	MROSupply
23	skf_bearing_16101_2	-	3	-	-	76.17	MROSupply
24	RushGears_2020_Z2M60	AISI 1045 Steel, cold drawn	2	3492.88	7850	11.18	-
					TOTAL COST ($)	2059.73	

DENSIFIER

ITEM NO.	PART NAME	MATERIAL	QTY.	MASS (g)	MASS DENSITY (kg/m^3)	COST ($)	SOURCE
1	Shaft-3	AISI 4340 Steel, normalized	1	194.51	7850	0.88	-
2	RushGears_2020_Z2M100	AISI 1045 Steel, cold drawn	1	4903.66	7850	15.69	-
3	RushGears_2020_Z2M20	AISI 1045 Steel, cold drawn	2	353.61	7850	1.13	-
4	Shaft-2	AISI 4340 Steel, normalized	1	242.13	7850	1.09	-
5	RushGears_2020_Z2M120	AISI 1045 Steel, cold drawn	1	7074.15	7850	22.64	-
6	Shaft-1	AISI 4340 Steel, normalized	1	148.64	7850	0.67	-
7	Motor Assembly	-	1	-	-	1000	Alibaba
8	Coupling15	AISI 304	1	16.93	8000	0.05	-
9	Coupling12	AISI 304	1	13.92	8000	0.04	-
10	SKF Bearing 16002 2	-	3	-	-	59.01	MROSupply
11	SKF Bearing 16101 2	-	3	-	-	76.17	MROSupply
12	Densifier Floor	AISI 4340 Steel, normalized	1	21278.39	7850	95.75	-
13	Connecting Rod	AISI 4340 Steel, normalized	1	486.47	7850	2.19	-
14	Piston	AISI 4340 Steel, normalized	1	2080.69	7850	9.36	-
15	Crankshaft1	AISI 4340 Steel, normalized	1	1673.02	7850	7.53	-
16	Skf Bearing NJ 2217 ECJ	-	2	-	-	200	MROSupply
17	Housing12dens	Grey Cast Iron	3	2348.96	7200	2.82	-
18	Housing15dens	Grey Cast Iron	3	2680.93	7200	3.22	-
					TAOTAL COST ($)	1498.24	

REACTOR

ITEM NO.	PART NAME	MATERIAL	QTY.	VOLUME (m^3)	MASS DENSITY (kg/m^3)	COST ($)	SOURCE
1	Reactor Structure	Carbon Steel ASTM A-106	1	0.027	7850	385.39	-
2	Catalyst	-	1	-	-	-	-
3	Upper Pipe	Carbon Steel ASTM A-106	1	0.00025	7850	3.46	-
4	Lower Pipe	Carbon Steel ASTM A-106	1	0.00036	7850	5.09	-
5	Pipe coupling	Carbon Steel ASTM A-106	1	3.06305E-05	7850	0.43	-
6	Pipe holder	Grey Cast Iron	2	0.00020	7200	3.39	-
7	gas pipe	AISI 316 Stainless Steel Sheet (SS)	1	0.00018	8000	4.44	-
8	Valve Control	-	1	-	-	58	Pneucons
9	Bunsen Burner	-	15	-	-	364.80	ARKAN
10	reactor table	Carbon Steel ASTM A-106	1	0.031	7850	436.77	-
11	Temperature Sensor	-	1	-	-	40.9	Enrgtech
					TAOTAL COST ($)	1302.68	

Total Cost	4885 $

Testing/Validation

	Product Mass Flow Rate (Kg/h)	Theoritical Calculation Product (%)	Simulation Calculation Product (%)
syngas	172.50	21%	19%
oil	575.44	69%	65%
char	83.93	10%	16%
sum	831.87	100%	100%

- The theoretically calculated overall mass balance of the process produced an average error of 5.8% with the values from the simulation.

- Various tests were conducted on the simulation to determine the best conditions that validate the specification of the process.

Conclusion

In conclusion, pyrolysis of plastics has proven to be an efficient and environmentally beneficial process, offering a sustainable solution to plastic waste by converting it into valuable products. The process was simulated using ASPEN Plus for the chemical analysis and SolidWorks for the mechanical design. The system was designed to process 20 tons of plastic waste per day, achieving a conversion rate of 65% to pyrolysis oil. The reactor was engineered to handle three common grades of plastic: HDPE, LDPE, and PP, ensuring versatility in waste processing. This approach not only mitigates environmental pollution but also creates an economically viable product, highlighting the potential of pyrolysis in addressing the global plastic waste crisis.