

Study of Profitability and Break-Even Analysis For Glycolytic Depolymerization Of Poly (Ethylene Terephthalate) (PET) Waste During Chemical Recycling Of Value Added Monomeric Products

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ABSTRACT: Cost estimation, profitability and break-even analysis for glycol tic depolymerization of poly (ethylene terephthalate) (pet) waste was carried out using a batch reactor. different costs were determined. obtained data was used to decide the feasibility of the process technology for its commercialization. the break-even point was estimated for the process that showed much more adequate return on the investment, which has an industrial significance.

Key words: *poly (ethylene terephthalate) depolymerisation, material balance, cost, profit, return, break-even point*

I. INTRODUCTION

The growing interest in pet waste recycling is due to the widespread use for various domestic and engineering applications. Ecological and economical considerations advocate the introduction of wide-scale recycling. Market is increasing rapidly and will further be boosted by current developments of pet grades, and produces high waste pet materials after use or during pet synthesis. Hence, among different methods of pet waste recycling, chemical recycling has recently been paid much more attention. [1–2] various researchers [3–12] has studied depolymerization of pet. application of these methods depends on end use of recovered products. appreciable amounts of monomeric products were recovered during chemical recycling of pet. [3–8] results of their studies did not report the feasibility of the method of recovery of monomers for commercialization. [1–12] hence, there were no required data available about cost estimation and profitability analysis that are essential for process selection during plant design for a new product. In absence of a reliable and sufficient necessary data of profitability and break-even analysis, reaction and

mass transport engineers are forced to scale-up the established reactors and or separating equipments in economically undesirable small steps. Additionally, the available reaction and or mass transport data are insufficient for designing new reactor and or separation equipment concepts with justifiable expenditure. for process selection as well as process development for optimal plant design, the knowledge of cost estimation, profitability and break-even analysis is required. hence, this study is undertaken to fulfill the industrial requirements for commercialization. however, literature does not show these types of study for glycol tic depolymerization of pet at optimal conditions. in this work cost estimation, profitability and the break-even analysis are studied for glycolytic depolymerization of pet waste at various optimal reaction conditions.

A. Theory

Although the technical parameters are influencing the selection and design of a given type of process may be unique, cost is usually only parameter relevant to all processes. Cost is often the parameter used to select the optimum process from the alternatives available. Economical information plays an important role in setting many states of the process. However, cost analysis is used to determine the minimum economic way of achieving the desired goal. An understanding of the economics involved in the process is important in making decision at both the engineering and management levels. Every engineer should be able to execute an economical evaluation of a proposed project. If the project is not profitable, it should obviously not be pursued and the earlier such a project can be identified, the fewer is the resources that will be wasted. Before the cost of a process can be evaluated, the factors contributing to the cost must be recognized. [13] An acceptable plant design must present a process that is capable of operating under conditions that will yield a

significant profit. Since net profit equals total income minus all expenses, it is essential that the chemical process engineer be aware of the different types of costs involved in manufacturing processes. Capital must be allocated for direct plant expenses, such as those for raw materials, labour, and equipment. Besides direct expenses, many other indirect expenses are incurred, and these must be included if a complete analysis of the total cost is to be obtained. Some examples of these indirect expenses are administrative salaries; product distribution costs, and costs for interplant communications.[13– 15] The selection of process using cost analysis is normally based on capital and operating cost. All equipment costs were reported [13] to be accurate to within 20 %. Variations in the total cost can be attributed to a number of variable factors such as cost of auxiliary equipment, new installation, local labour cost, engineering overhead, location and accessibility of plant site, and type of industry (installation work). [13]

A capital investment is required for any industrial process, and determination of the necessary investment is an important part of a plant design project. The total investment for any process consists of fixed capital investment for physical equipment and facilities in the plant alongwith working capital that must be available to pay salaries, keep raw materials and products on hand, and handle other special items requiring a direct cash outlay. Moreover, in an analysis of costs in industrial processes, capital investment costs, manufacturing costs, and general expenses including income taxes must be taken into consideration. [13, 14] The flow chart for the glycolytic depolymerization of PET using ethylene glycol (EG) was developed for complete recovery of monomers (Figure 9) [8] at various optimal process conditions. Based on the various information of glycolytic depolymerization process of PET, [8] the material balances were evaluated for raw materials as well as products. In present study, costing of fixed capital investment was under taken by calculating initially the total equipment costs for the depolymerization process. Then using the percentage of purchased equipment costs the fixed capital investment was evaluated. Then total product cost and hence total expenses were calculated. Total annual income, gross profit, and net profit were computed. Finally, payback period, rate of return and break-even point analysis were computed.

II. EXPERIMENTAL

A. Material, Chemicals And Reagents

PET used was procured from Garaware Polyesters, Aurangabad, M.S., (INDIA). Here waste just mean materials left over after some products were made from raw material that was free from any additives / plasticizers. The other materials used were neutral water, methanol, HCl, CaO, sodium sulfate, ethylene glycol, zinc acetate, urea, etc., obtained from s. d. Fine Chemicals (INDIA). These chemicals were used as received without further purification.

B. Glycolysis of PET

Glycolysis reactions [8] were carried out in a 1 L four-necked batch reactor at various temperatures ranging from 100-220 °C at the interval of 10 °C and 1 atm pressure. Reactor was equipped with a thermometer and two reflux condensers. A stirrer was put in reactor to ensure proper mixing. Reaction was carried out by taking 10 g PET in 40 mL of ethylene glycol (EG) using glycolysis catalyst (i.e., 0.002 mol of zinc acetate) with 4 pieces of porcelain for different periods of time ranging from 30 to 150 min. Different particle sizes ranging from 50 to 512.5 µm of PET were taken for this reaction (separately). After completion of glycolysis reaction of PET, the batch reactor was removed from heating mantle and 50 mL of boiling neutral water was slowly introduced into reaction mixture. Whole reaction mixture was quickly filtered.

Unreacted PET was collected, washed with neutral water, dried in controlled oven at 95 °C until its constant weight that was recorded.

Remaining filtrate was methanolized (second step required in process) with additional catalyst (i.e., 0.002 mol of urea) for 30 min at 190 °C and 1 atm pressure. Reaction mixture was cooled in an ice-bath. White crystalline flakes of DMT were formed. It was filtered and washed with 50 mL of cooled neutral water in order to remove catalysts, and dried in a controlled oven at 95 °C until its constant weight, which was recorded.

From remaining liquid phase, EG was separated using salting-out method [2, 8] by introduction of sodium sulfate. Both monomeric products (DMT and EG) were analyzed qualitatively and quantitatively. Percent depolymerization of PET, yield of DMT and yield of EG were determined by gravimetry and defined in following ways.

$$\text{A. Depolymerization of PET (\%)} \\ = \{(W_{PET,i} - W_{PET,R}) / W_{PET,i}\} \times 100 \quad (1).$$

$$\text{Yield of DMT (\%)} \\ = \{m_{DMT,O} / m_{PET,i}\} \times 100 \quad (2).$$

$$\text{Yield of EG (\%)} \\ = (m_{EG,O} / m_{PET,i}) \times 100 \quad (3).$$

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7	Yard Improvements	10	67100
8	Service Facilities (Installed)	55	369050
9	Land	6	40260
Total Direct Cost (TDC)			Rs 1966030

Indirect Costs:

Sr. No.	Item	% TEC	Cost (Rs)
1	Engineering And Supervision	32	214720
2	Construction Expenses	34	228140
3	Total Indirect Cost: T I D C:		Rs 442860

Total Direct Costs And Indirect Costs:
Rs 2408890

Other Charges:

Sr. No.	Item	% TD&IDC	Cost (Rs)
1	Contractors Fees	5	120445
2	Contingency	10	240889

Fixed Capital Investment = Rs 2770224.

Working Capital Investment = 74 % TEC = Rs 496540.

Total Capital Investment = Rs 3266764.

Total Product Cost:

Manufacturing Cost:

Direct Production Costs: Raw Materials Cost:

Sr. No.	Raw Material	Raw Material (Kg / Yr)	Cost (Rs / Kg)	Cost (Rs / Yr)
1	PET	103486	22	2276692
2	EG	413944	200	82788800
3	CaO	35000	70	2450000
4	Neutral Water	537600	5	2688000
5	HCl	19200	40	768000
6	Na ₂ SO ₄	76800	54	4147200
7	Zinc Acetate	5175	200	1035000
8	Urea	1243	60	74580
9	Methanol	206972	55	41383460

Total Raw Materials Costs = Rs 107611732.

Operating Labour Costs:

Sr. No.	Post	1) No. of Posts	Pay (Rs/ Month)	Pay (Rs /yr)
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1		1	12000	144 000
2	Plant Manager	1	6000	720 00
3	Shift Engineer	3	4000	144 000
4	Shift Supervisor	3	3000	108 000
5	Operator	15	2500	450 000
6	Skilled Labour	10	2000	240 000
7	Unskilled Labour	30	1500	540 000

Total Operating Labour Costs = Rs 1698000.

Office Materials And Clerical Expenses = 10 % TOLC = Rs 169800.

Utilities = 75 % TOLC = Rs 1273500.

Maintenance And Repairs = 2 % FCI = Rs 55405.

Operating Supplies = 10 % M & R = Rs 5541.

Laboratory Charges = 10 % TOLC = Rs 169800.

Patents And Royalties = 10 % TOLC = Rs 169800.

Fixed Charges:

Depreciation = 10 % FCI + 2 % Building Value = 277023 + 3892 = 280915.

Local Taxes = 1 % FCI = Rs 27703.

Insurance = 0.4 % FCI = Rs 11080.

Plant Overhead = 50 % TOLC = Rs 849000.

General Expenses:

Administrative Costs = 15 % TOLC = Rs 849000.

Distribution And Selling Costs = 15 % TOLC = Rs 254700.

Research And Development Costs = 15 % TOLC = Rs 254700.

Financing (Interest) Costs = 10 % FCI = Rs 277023.

Total Product Costs = Manufacturing Costs + General Expenses.

Total Product Costs = Rs 113957699.

Total Expenses = Total Capital Investment + Total Product Costs

Total Expenses = 3266764 + 113957699 = Rs 117224463.

Profitability Analysis:

Total Product Annual Income:

Sr. No.	1) Products	Production (Kg/Yr)	Cost (Rs/Kg)	Income (Rs/Yr)
1	3) DMT	76800	1500	115200000
2	EG	24549	200	4909800

Total Product Annual Income = Rs 120109800.

B. Gross Profit = TPAI – Total Expenses = 120109800 – 117224463

= Rs 2885337.

C. Net Profit = Gross Profit – Income Tax. = Gross Profit – 40 % Gross Profit

= 60 % Gross Profit = Rs 1731202.

Payback Period = $(FCI / NP) = (2770224 / 1731202) = 1.6 \text{ Yrs} = 19.2 \text{ Months}$.

Rate of Return = $(NP / FCI) \times 100 = (1731202 / 2770224) \times 100 = 62.5 \%$.

Break Even Analysis:

Break Even Point (Units) = $[FCI / (\text{Selling Price per Unit} - \text{Variable Cost per Unit})]$.

= $[2770224 / (1500 - 1350)] = 18468.16 \text{ Kg}$.

Break Even Point (as a % capacity) = $[BEP (\text{units}) / \text{Total capacity of Product}] \times 100$.

= $(18468.16 / 76800) \times 100 = 24 \%$.

Conclusion

Cost estimation, profitability and break-even analysis for glycolytic depolymerization of poly (ethylene terephthalate) (PET) waste was revealed that the rate of return on investment and payback period is pretty good that has an industrial significance. Various cost analysis data is used to decide the feasibility of the process for industrial application. The break-even point (as a % capacity), payback period and rate of return were estimated that were recorded as 24 %, 1.6 years and 62.5 % respectively for the process. Payback period, rate of return and break-even point values indicates that the much more excellent viability of the process of glycolytic depolymerization of PET at various optimal conditions.

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