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**RESEARCH ARTICLE**

# CAPITAL AND OPERATING COST CAN BE SAVED BY USING MULTI-TUBULAR CATALYTIC REACTOR IN PLACE OF CONVENTIONAL FIXED BED CATALYTIC REACTOR

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**ABSTRACT**

If we use multitubular reactor in place of conventional multibed reactor in manufacturing of Ethylbenzene, we do not need to use heat exchangers (reaction is extremely exothermic) So, here we can save capital cost and operating cost of around three to four heat exchangers. Hence, we can ultimately save energy and money. Here, we used HTRI programme for heat exchanger. We had to carry out manual calculations for design of heat exchangers to find out capital cost. We found out energy saving also. So, here attempt is made to give a thought of changing process or equipment during we decide our project and we can save energy and money.



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## INTRODUCTION

In case of exothermic and endothermic reaction carried out in multiple catalytic fixed beds reactors Figure 1 or fixed beds in series reactors shown in Figure 2, we need to provide Heat exchanger between the reactors or catalyst beds as shown in Figure 1 and 2 to add or remove heat to maintain temperature of reaction. In place of using above arrangement, we can think of using multi-tubular reactor shown in Figure 3. If we need length of tube much more than height of bed for multi-tubular reactor, we can have arrangement shown in Figure 4 for better heat transfer.

Here is a case study. For production of Ethylbenzene, In place of using conventional reactor like Figure 1 and 2, We have used multi-tubular reactor as shown in Figure 3. We do not need to use heat exchangers as shown in Figure 1 and 2 as heat exchange is sufficient in reactor itself.

## RESULTS AND DISCUSSION

We have calculated capital cost and operating cost for all three heat exchangers for production of 8.374 tones / hr Ethylbenzene. Details of all the three heat exchangers (kettle type) including results obtained by HTRI software is given in Table 1.

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### Capital cost

Capital cost of Heat exchanger 1 obtained by calculations is:
Cost of shell: Carbon steel SA Gr 70 can be used as MOC for shell. Required length of shell 4.81m, Outside dia. of shell is 1.83 m, Inside dia. of shell is 1.825 m. Thickness of shell 5 mm ., Cost of shell is Rs.44,184. Cost of tubes: Required MOC for tubes is SS-316. No. of tubes required are 92. Required length of tubes 4.8 m.Outside dia. of tubes is 0.0381 m. Inside dia. of tubes is 0 .034 m. Thickness of tubes is 2mm., Cost of shell is Rs.2,99,281.

**Cost of head 1 (Torispherical):** MS can be used as MOC. Blank dia required 1.116m, Thickness of plate required is 0.0151m. Cost of head 1 is Rs.9,486.
Cost of head 2 (Torispherical) MOC required for head 2 is SS-316. Blank dia required 1.132m, Thickness of plate required is 0.01225m. Cost of head 2 is Rs.43,477.
**Cost of tube sheet:** 01 tube sheet is required here. MOC required is Incoloy alloy 1800. Thickness required 72mm. Dia. of sheet required 1.027 m. Cost of sheet is Rs. 2,86,646.

Total Cost of Heat Exchanger-1 is approximately Rs. 3,96,428
Similarly, Capital cost of Heat Exchanger-2 is Rs. 2,45,721 and Heat Exchanger-3 is Rs. 1,94,496 Capital Cost saved for all the three Heat Exchanger is Rs. 8,36,646 (Here, cost of designing, fabrication and small parts is not included. Only cost of material for major parts are calculated here)

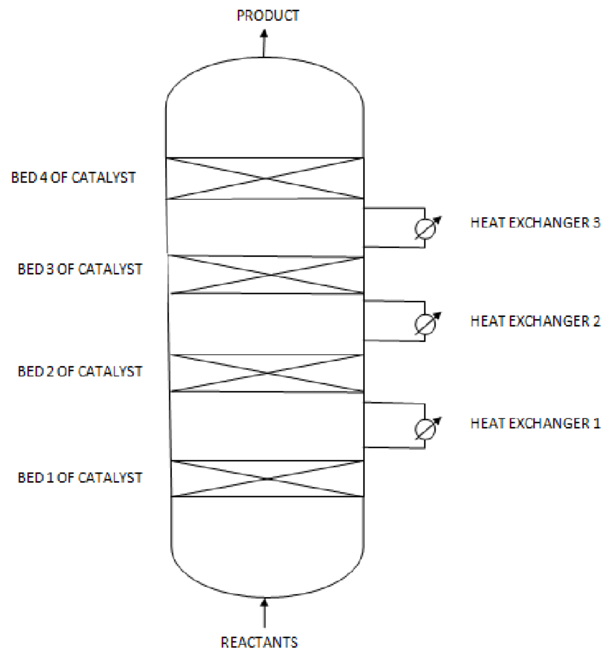


**Figure 1. Fixed beds catalyst in series reactor**

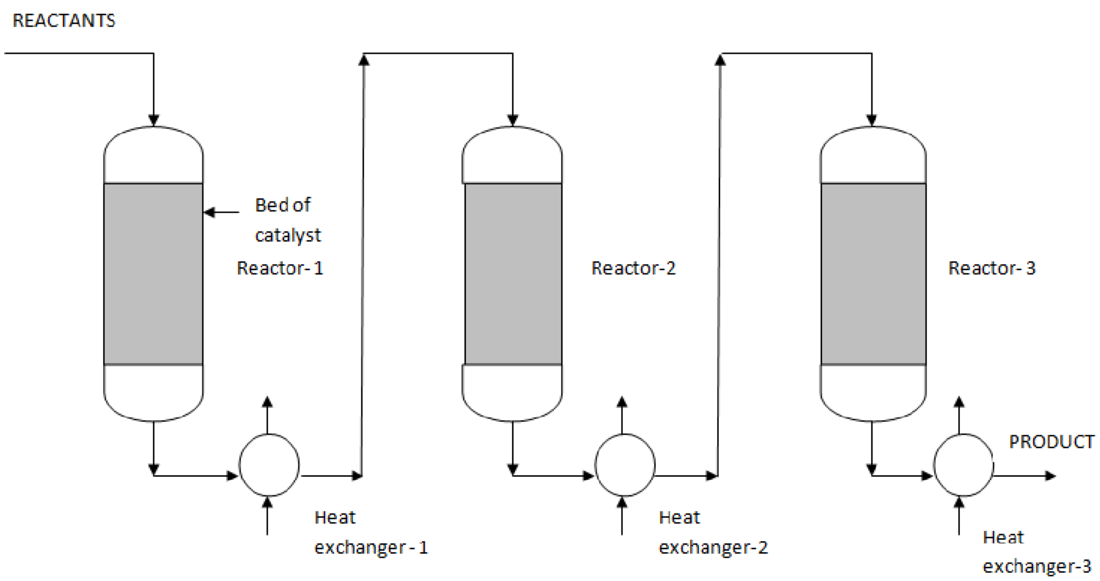


**Figure 2. Multiple catalytic bed reactors with external heat exchangers**

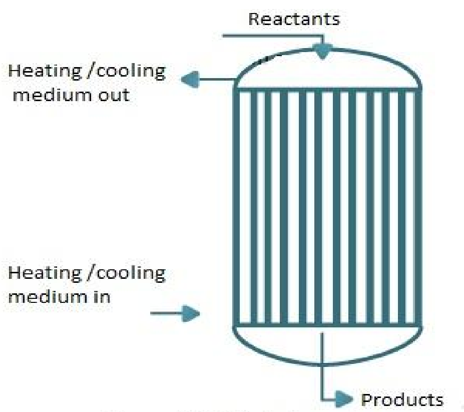


Figure-3 Multitubular reactor

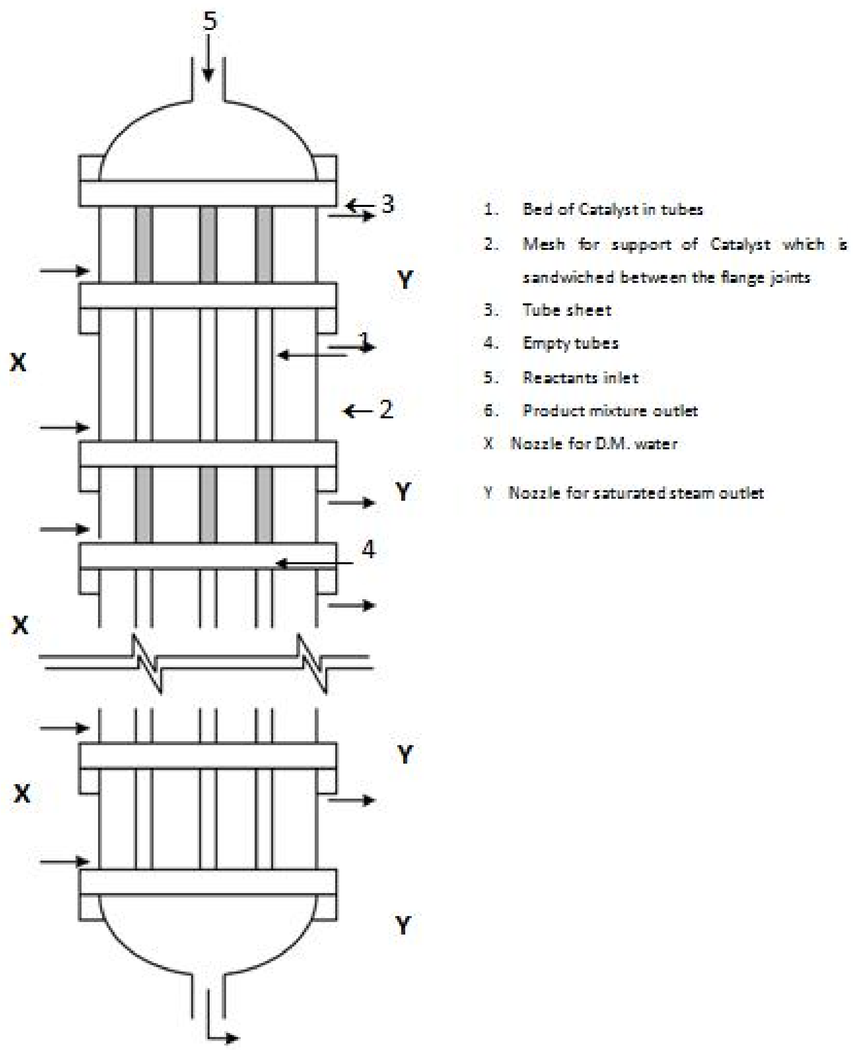


**Figure 4. Multitubular reactor**

Final summary

| | HE-1 | HE-2 | HE-3 |
|---|---|---|---|
| Hot fluid – gas mixture | Tube side | Tube side | Tube side |
| Cold fluid – water | Shell side | Shell side | Shell side |
| Flow rate of gas mix. Kg/s | 3 | 3 | 3 |
| Water flow rate, kg/s | 1.8301 | 0.8487 | 0.40 |
| Inlet temp of gas mix | 948 | 649 | 499 |
| Outlet temp of gas mix | 350 | 350 | 350 |
| Total inlet press and pressure drop shellside | 1000 and 7.7 kPa | 1000 and 6.35 kPa | 1000 and 3.1 kPa |
| Inlet temp of water | 25 | 25 | 25 |
| Outlet temp of steam | 180 | 180 | 180 |
| MOC for tube | SS 316 | SS316 | SS316 |
| Overall U | 270 W/m2K | 313.5 W/m2K | 426.7 W/m2K |
| Delta P for shell | 7.3 | 6.3 | 3.1 |
| Delta P for tube | 7.1 | 34 | 52 |
| Total HE area, $m^2$ | 52.9 | 19.53 | 12 |
| No. of tubes | 92 | 34 | 24 |
| Tube inside dia., mm | 34 | 34 | 34 |
| Tube side passes | 2 | 2 | 2 |

Operating cost for all three Heat Exchangers in this case is negligible (Rs 1301 per yer) because here steam of very high pressure (10 bar) is generated. If there is no phase change high operating cost can be saved every year.

## Conclusion

If multi tubular reactor is used in place of multiple fixed bed in series reactor or fixed beds in series reactor considerable capital and operating cost can be saved for other processes also. In case of replacing with multiple catalytic fixed bed reactors as shown in figure 1. cost of vessels can also be saved.

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