Multi objective optimization of triple concentric tube heat exchanger

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Abstract:

In this study, the heat transfer and pressure drop properties of a triple concentric tubes exchanger were optimised using only CFD effects. The response surface technique (RSM) and GRA methods were used to generate an ideal response as well as a functional relationship primarily based on the examined variety of design/control parameters. The Nusselt number and friction factor were the response variables, while the Reynolds number and length to hydraulic diameter ratio were the design variables. A mathematical model is built using the input variable with RSM in this study.

Keywords: CFD, numerical modelling, optimization, thermal hydraulic performance, Response surface methodology, triple concentric-tube.

1. Introduction

TRIPLE CONCENTRIC TUBE HEAT EXCHANGERS

A double tube heat exchanger is the most common heat exchanger kind used in a variety of applications. Its operation is based on the transmission of heat between two pipes containing cold and hot fluids.

It has its significance in freezing, boiling drying, dairy, and pharmaceutical, food, pasteurization and chemical industries. In order to manage high-temperature differences, the heat exchange area should be increased, which could be possible only by increasing the heat exchanger's length. TTHE

It has three concentric tubes, or three compartments, referred to as the inner tube, inner annulus, and outer annulus, respectively. The target fluid, whose temperature changes are of primary relevance for application fulfilment, must flow within the inner annulus in order to maximise the heat exchanger's efficiency.

When compared to a twin tube device (which only has one heat exchange surface), the inner annulus contains two heat exchange surfaces (inner tube outer surface and outer tube inner surface), which increases the heat exchange area of the heat exchanger slightly and thus increases the heat exchange speed. It will also improve the efficiency of the heat exchanger. As a result, when compared to double tube systems, the length of the heat changer required for consistent temperature differentiation is reduced. Parallel flow and counter flow are two flow arrangements for a twin tube heat exchanger. Three fluids pass via the triple tube heat exchanger (TTHE), resulting in four distinct combinations. Eight alternative flow configurations occur when the above setup is compared.

RESPONSE SURFACE METHODOLOGY OF EXPERIMENT

It's commonly used in the industry because it's the most effective technique for meeting welding requirements. This research looked at how to prepare low-cost goods and how to improve welding defects so that they work properly. This type of technique is commonly used to minimise costs and increase product quality, and it logs as functions of desired performance. Via rigorous design of experiments, the approach and variance in a process are minimised to aid in data interpretation and prediction of optimal outcomes. RSM is an effective modeling tool to establish a relationship between controllable input and their dependent output response. The studies concentrated on the modeling and optimization of combustion and thermal performance of the biodiesel in the dual-fuel engine through RSM are even rarer The following are the key RSM objectives and measures for the parameter design phase:

Choosing an experiment design and optimizing Based on literature survey, it has observed that Taguchi method is most easy and robust method. Also it is cost effective as it identifies the minimum number of experimental trials needed by suggesting correct combination of different design parameter needed for analysis of test results avoiding unnecessary data collection and their analysis. So Taguchi DoE has been used to identify the correct combination of selected design factor and their levels in present study. For the present study, factors and levels were selected based on literature review are mentioned in Table 4.

Table 2.1 Design variables and levels of their values.

		Coded values		
Design factors	Symbol	-1	0	1
Reynolds number	Re	2500	6250	10,000
Length to hydraulic diameter ratio	L/Dh	140	180	220

Table 2.2 Levels of design factors and CFD results of response variables.

	Design factors (Uncoded values)		Response variables (Uncoded values)	
Run Order	**Re**	**L/Dh**	**Nu**	**F**
1	2500	140	20.5885	0.0662134
2	2500	180	16.1273	0.0518672
3	2500	220	13.1995	0.0424368
4	6250	140	30.9013	0.047571
5	6250	180	24.2055	0.037264
6	6250	220	19.8372	0.0304887
7	10000	140	36.8984	0.0398602
8	10000	180	28.9031	0.0312238
9	10000	220	23.6792	0.0255468

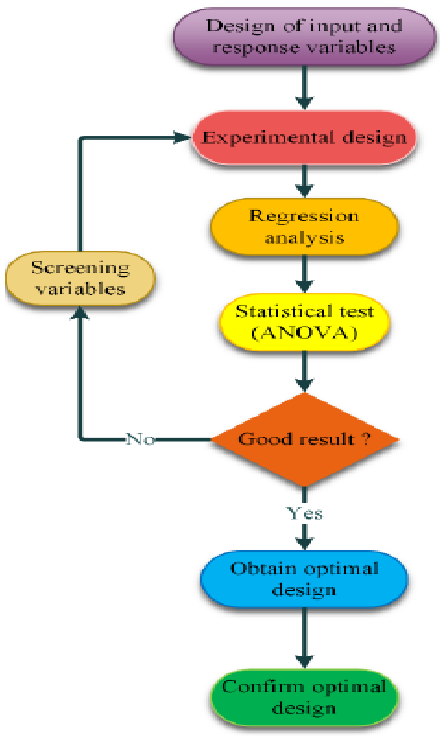

Fig 5.2 Response surface methodology

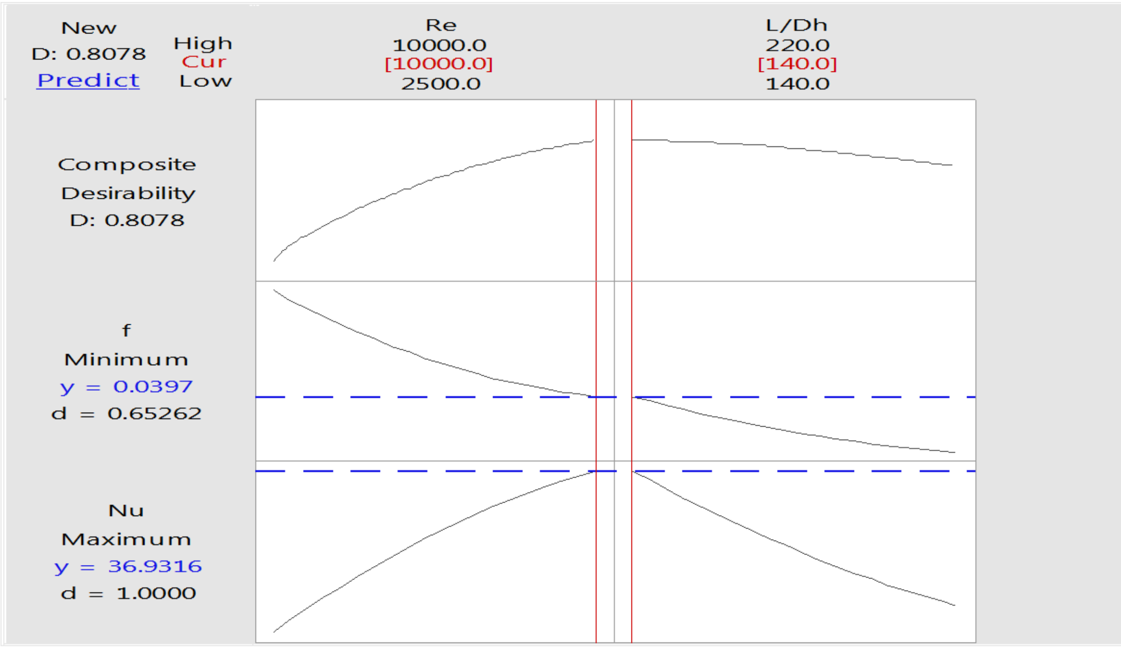

Fig 5.3 Response surface methodology

5.2 Confirmation test

Table 5.1 Multi-objective optimization results

Design factors	Level	Optimal Level	Experimental	Predicted (RSM)	Error (%)
(Nu) Nusselt number	A	A_2	36.8984	36.9316	0.0332
Friction factor (f)	B	C_1	0.0398602	0.0397	0.0001

The predicted value of the response variables is precisely closer to the numerical results and hence, it has helped in reducing the size of the required data as the RSM provides useful interaction between the various parameters of the system. The model satisfies a desired 95% confidence level. The values in Table 5.1 shows the experimental and predicted values, ie error is at an acceptable level.

CONCLUSION AND FUTURE SCOPE

1. Based on the results of numerical simulation and multi-objective optimization. From Figure 3.3 that the first Level provides maximum value of Nusselt number. (a) Reynolds number A1 2500 (b) Length to hydraulic diameter ratio), B2 180

2. From Figure 3.3 that the first Level provides minimum value of pressure drop (friction factor) (a) Reynolds number A1 2500 (b) Length to hydraulic diameter ratio), B2 180.

3. Table 4.3 shows the ANOVA result for friction factor. It is observed that the Reynolds number (P=0.000) (54.08 %) is most influences the friction factor followed by hydraulic diameter ratio (P= 0.000) (40.33%)

4. The F-test determines whether the parameters are significantly different statistically. The greater the impact on the friction factor performance characteristics, the higher the F value [15]. For Reynolds number (P=0.000), larger F values are found (58.57 %)

5. Table 4.3 shows the ANOVA result for Nusselt no.. It is observed that the Reynolds number (P=0.000) (54.08 %) is most influences the friction factor followed by hydraulic diameter ratio (P= 0.000) (37.53%)

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