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Study on The Reaction Performance of C4 Olefins Based on Hierarchical Regression Model

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Abstract: In daily life, olefins and their derivatives are widely used, at the same time, olefins has been widely used in chemical manufacturing and medicine production, the use of olefins in the global scope and use demand is growing, subject to the conditions of fossil energy decrease, explore greener, optimization of energy saving of olefins preparation technology is particularly important. In this paper, the reaction performance of catalyst combination and temperature for C4 olefin analysis by coupling ethanol was studied. For question 1, According on the experimental test results of 21 sets of different catalyst combinations or different catalyst loading methods given in Annex 1, For the various independent variables and the dependent variables in this question, Build a relationship model between the various variables, It was analyzed using a fitted interpolation prediction model, By using the data fitting algorithm and the linear regression model, The relationship between the ethanol conversion rate and temperature and the selectivity of C4 olefins and temperature was further analyzed; Using using fitting interpolation prediction model and data fitting algorithm for Annex 2, According to their image analysis, under the same experimental conditions, Effect of time on the reaction performance of the experiment. For problem 2, through comprehensive analysis of the data given in attachment 1 and attachment 2, according to the influence of different catalyst combination and temperature on the ethanol conversion rate and C4 olefins selective size, first using the control variable method for data stratification analysis, from the same catalyst combination different temperature, different catalyst combination, the same experimental conditions different catalyst loading way three levels. Hierarchy one uses quantitative analysis, hierarchy two uses the multivariate factor ANOVA model, and hierarchy three uses comparative analysis. Finally, the conclusion analysis of three levels is comprehensively discussed, and the influence degree of different catalyst combinations and temperature on ethanol conversion rate and C4 olefins selectivity is discussed. For problem 3, according to the Appendix: Interpretation of nouns and appendix description, the value of the C4 olefins yield is equal to the product of the ethanol conversion rate and the selectivity of the C4 olefins. About temperature, Co load, Co / SiO_2Conduct multiple analysis of variance and weight, and then order the reaction performance of the four variables. The hierarchical regression model and linear regression model were established to develop the catalyst combination and temperature in the same experimental conditions below 350 degrees and the same experimental conditions. Aiming at problem 4, through the comparative analysis of all catalyst combinations and temperature scheme in Annex 1, find out the experimental group with a lack of control, using the control variable method and analogy reasoning to supplement the catalyst combination and temperature scheme, so as to improve the accuracy of the experimental data and enhance the reliability of the conclusion.

Keywords: Fit interpolation prediction model, Weight analysis, Multiple factor analysis of variance model, Hierarchical regression model.

1. Restatement of the Problem

In recent years, the demand for propylene at home and abroad has been far greater than that for ethylene. C4 olefins is widely used in the production of chemical products and pharmaceuticals, and ethanol is the raw material for the production of C4 olefins. Through the catalyst combination design of this problem, when the catalyst combination (i. e., Co load, Co / SiO2 and HAP loading ratio, ethanol concentration) and temperature will affect the selectivity of C4 olefins and C4 olefins yield.The attachment is a series of experimental data done by a chemical laboratory for different catalysts at different temperatures.

(1) From the data provided in Annex 1, the relationship between the ethanol conversion rate and temperature, and the selectivity of C4 olefins and temperature were analyzed separately within each catalyst combination. By analyzing the test results of the catalyst combination given at different times at 350 degrees provided in Annex 2, the relationship between the time and the measured values is obtained.

(2) Through the comprehensive analysis of Annex 1, the effects of different catalyst combinations on ethanol conversion rate and C4 olefins selectivity at the same temperature, and the effects of different temperature changes on ethanol conversion rate and C4 olefins selectivity size during the same catalyst combination were explored respectively.

(3) The C4 olefins yield of the C4 olefins is calculated using the ethanol conversion ratio and C4 olefins selectivity multiplication, and analyze the catalyst combination and temperature under the same experimental conditions, that is, the ethanol conversion ratio and C4 olefins selectivity are as high as possible, and discuss whether the previous catalyst combination and temperature selection scheme can make the C4 olefins yield as high as possible if the experimental temperature is below 350 degrees, and a better analysis.

(4) According to the analysis results of the above three problems, the experimental conditions of five more experiments are added to prove the conclusion of the previous three questions and make the conclusion of the experiment more realistic and reliable.

2. Problem Analysis

At present, the industrial development still occupies the important construction goal of China, under the new situation of the "14th Five pivotal role in the development of China's national economy. With the deep adjustment of the global petrochemical industry structure, China's chemical industry is also facing unprecedented challenges and opportunities [1]. C4 olefins as one of the important chemical raw materials, widely used in the production of chemical products and medicine, the utilization rate is relatively low, with the shortage of fossil energy production, and avoid more serious damage to the natural environment, research more scientific more environmental energy production mode more urgent and important, according to the 1993 chun found direct coupling theorem [2], Exploring the process of ethanol catalytic coupling to prepare C4 olefins has a more reliable theoretical basis [3].-Year Plan", China's industrial development will encounter new opportunities and new challenges. The chemical industry plays a

2.1. Problem 1 Analysis

According to the attachment 1,21 sets of data, by MATLAB using the plot function, and the correlation analysis using the basic fitting, find out the best scatter map function image, and the function equation, study the relationship between ethanol conversion rate and temperature, C4 olefins selectivity and temperature.

According to the data on the results of ethanol conversion rate and C4 olefins selectivity in Annex 2, and the relationship between ethanol conversion rate and C4 olefins selectivity and time at 350°were plotted respectively, based on which the test results of the given catalyst combination at different times at 350°were analyzed.

2.2. Problem 2 Analysis

The line chart of ethanol conversion rate and C4 olefins selectivity at different temperatures in the same catalyst combination, drawn by quantitative analysis in Question 1; According to the result data of Annex 1 on the ethanol conversion rate and C4 olefins selectivity caused by different catalyst combinations at the same temperature, Performing a multivariate factor ANOVA model building, The influence of each factor on the selectivity of ethanol conversion rate and C4 olefins was judged through the rationality analysis; By the observational analysis, Find out the same catalyst assembly in class A and the same catalyst combination in class B catalyst assembly, Comparing it at the same temperature, Effect of different catalyst loading methods on ethanol conversion rate and C4 olefins selectivity. Through the analysis of the above three comparison results, the effects of different catalyst combinations and temperature on the ethanol conversion rate and the C4 olefins selectivity were analyzed.

2.3. Problem 3 Analysis

The value of the C4 olefins yield is equal to the product of the ethanol conversion rate and the selectivity of the C4 olefins. According to the data in Annex 1, the influence of temperature, Co load, Co / SiO2 and HAP loading ratio, and the drip rate of ethanol on the C4 olefins yield was analyzed by the multiple factor variance model, and the influence of the four independent variables on the C4 olefins yield was ranked. The hierarchical regression model was developed on the linear regression model with temperature, Co load, Co / SiO2 and HAP loading ratio, ethanol drop rate as the independent variables, and C4 olefins yield as the dependent variable, and the correlation coefficient was obtained.

Finally, through the above analysis and function construction, the catalyst combination and temperature of the C4 olefins yield and the C4 olefins yield are developed below 350 degrees.

2.4. Problem 4 Analysis

On the basis of the analysis of the discussion results of the first three questions, through comparative analysis and analogy reasoning judge all catalyst combination and temperature in attachment 1 has lack of comparison group experimental group, and put forward to confirm the first three questions conclusion analysis of the experimental combination conditions, namely develop suitable catalyst group and temperature of the experimental conditions.

3. Model Hypothesis

(1) Suppose that the data obtained from the Internet is true and reliable;

(2) Suppose that the ethylene conversion rate, the selectivity of C4 olefins and the C4 olefins yield together reflect the experimental reaction performance;

(3) The reaction times of the different catalyst combinations in Annex 1 are the same at different temperatures;

(4) It is assumed that all the experiments in this paper are conducted in an appropriate environment;

(5) Suppose that the other experimental conditions not mentioned in the experiment designed in Q 4 are the same as in the control group.

4. Symbolic Description

symbol	explain
T	temperature
α	Ethanol conversion rate of (%)
β	Selective (%) of the C4 olefins
δ	The C4 olefins yield of (%)
I	Co Load Volume (wt /%))
h	Charge ratio of Co / SiO2 to HAP
v	Dropping rate of ethanol (ml/min)
$\bar{\alpha}$、$\bar{\beta}$、$\bar{\delta}$	average value of α, β, δ
M	median
S	variance
$\bar{S}$	standard error
P	crest value
Q	least value
θ	skewness
μ	kurtosis
P	Significance coefficient
F	Difference value test results
df	free degree
B	There are the coefficients in the constant case
t	Statistical value
R^2	Degree of fit for the curve review
VIF	multicollinearity severity

5. Model Establishment and Solution

5.1. The Establishment and Solution of the Problem-1 Model

Through the observation and analysis of the performance data table in Annex 1, it is found that there are five different combinations of temperature (T). After comparative screening, 250 degrees, 275 degrees, 300 degrees and 350 degrees included in each group of temperature (T) are selected as the reference indexes to calculate and analyze the test data in the catalyst experiment. The catalyst combination was disassembled and analyzed, and refined into Co loading (I), Co/SiO2 and HAP loading ratio (h), and ethanol dripping rate (v) for subsequent quantitative analysis of data. The results are shown in support material 1.

According to annex 1 of 21 groups of different combination of catalyst or catalyst loading way of ethanol for C4 olefin selectivity and conversion rate of the data, the separation of ethanol conversion rate (α) respectively, C4 olefin selectivity (β) , time and temperature data, the fitting interpolation model, through the data fitting method obtains the function relation between the combination of catalyst; According to Annex 2, the line chart of the relationship between ethanol conversion rate (α), C4 system selectivity (β) and time in this set of data is drawn respectively. The detailed analysis process model is as follows, see Figure 1.

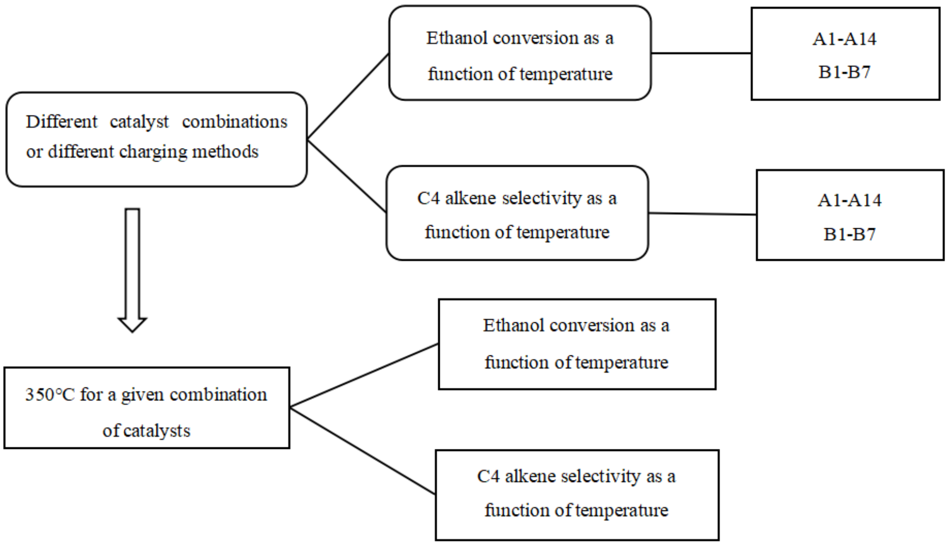


Figure 1. Problem 1 Analytical Process Model

5.1.1. Model Establishment

According to the data of 21 groups of experiments given in Annex 1, the data of group A1 were selected. In the same catalyst combination, MATLAB was used to establish the fitting interpolation prediction model for temperature (T), ethanol conversion rate (α) and selectivity of C4 olefin (β), and the functional relationship was obtained through data fitting. The results are as follows, see FIG. 2. Support materials 2 and 3 are used as data fitting.

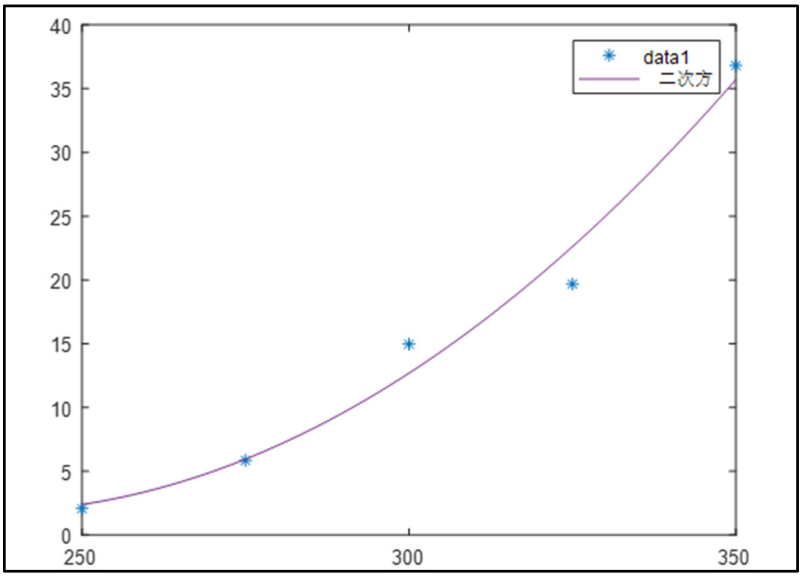


Figure 2. Relationship between ethanol conversion rate (α) and temperature (T) in group A 1

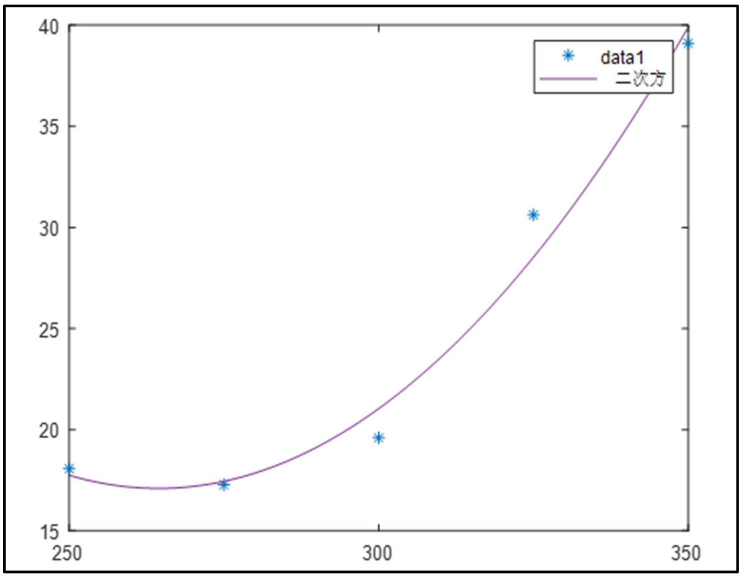


Figure 3. Relationship between selectivity and temperature (T) of alkenes in C4 in Group A 1

According to the basic fitting of the scatter plot, we can obtain the function relationship, the relationship of the ethanol conversion rate (α) and the temperature (T) in group A1:

$$\alpha = 0.0025T^2 - 1.2T + 1.4e + 2$$

Relationship between selective ((β) and temperature (T) of C4 olefins in group A1:

$$\beta = -0.0021T^2 + 1.4222T - 190.7834$$

The data in Annex 2 were compared with the relationship between the ethanol conversion rate (α) and time, the selective ((β) and time of C4 olefins, and other data and time, and the line chart of their relationship was drawn for analysis.

5.1.2. Model Solution

Through fitting analysis of the A1 data in Annex 1 and analogy processing analysis of the remaining 20 sets, the relationship functions of ethanol conversion rate (α), selectivity (β) and temperature (T) in different catalyst combinations are obtained as shown in Table 1.

By analyzing and comparing the data in Annex 2, the broken line diagram of the relationship between ethanol conversion rate (α) and time, selectivity (β) and time of C4 olefins, and other data and time is drawn as shown in Figure 4 and in Supporting Material for details 4.

1**Table 1.** Function of ethanol conversion rate (α), C4 olefins selectivity (β) and temperature (T) in different catalyst combinationsα

Catalyst combination	The relationship function of the ethanol conversion rate (α) and the temperature (T)	A function of the selectivity (β) and temperature (T) of C4 olefins
A 1	$\alpha = 0.0025T^2 - 1.2T + 1.4e + 2$	$\beta = -0.0021T^2 + 1.4222T - 190.7834$
A 2	$\alpha = -0.00074T^2 + 1.1T - 2.3e + 2$	$\beta = 0.0031T^2 - 1.6463T + 234.7454$
A 3	$\alpha = 0.0015T^2 - 0.49T + 41$	$\beta = 0.0006T^2 - 0.0314T - 23.7920$
A 4	$\alpha = 0.00036T^2 + 0.35T - 1.1e + 2$	$\beta = 0.0012T^2 - 0.5624T + 72.7734$
A 5	$\alpha = 0.0032T^2 - 1.7T + 2.3e + 2$	$\beta = 0.0011T^2 - 0.4995T + 57.8837$
A 6	$\alpha = 0.0017T^2 - 0.58T + 52$	$\beta = 0.0022T^2 - 1.2336T + 176.6157$
A 7	$\alpha = -0.00027T^2 + 0.56T + e + 2$	$\beta = 0.00112 - 0.5651T + 74.7810$
A 8	$\alpha = 0.0018T^2 - 0.8T + 97$	$\beta = 0.0007T^2 - 0.2446T + 19.8190$
A 9	$\alpha = 0.0024T^2 - 1.3T + 1.9e + 2$	$\beta = 0.0001T^2 + 0.2180T - 53.4302$
A 10	$\alpha = 0.0018T^2 - 0.99T + 1.4e + 2$	$\beta = 0.0007T^2 - 0.4036T + 59.7113$
A 11	$\alpha = 0.0023T^2 - 1.3T + 1.8e + 2$	$\beta = 0.0002T^2 - 0.0675T + 5.5858$
A 12	$\alpha = 0.0019T^2 - 0.95T + 1.2e + 2$	$\beta = 0.0009T^2 - 0.3829T + 45.3248$
A 13	$\alpha = 0.0022T^2 - 1.2T + 1.6e + 2$	$\beta = -0.0003T^2 + 0.3425T - 64.3329$
A 14	$\alpha = 0.0022T^2 - 1.1T + 1.4e + 2$	$\beta = 0.0010T^2 - 0.4940T + 64.8629$
B 1	$\alpha = 0.0019T^2 - 0.95T + 1.2e + 2$	$\beta = 0.0009T^2 - 0.3654T + 39.0678$
B 2	$\alpha = 0.0025T^2 - 1.4T + 1.9e + 2$	$\beta = 0.0010T^2 - 0.4028T + 41.3295$
B 3	$\alpha = 0.0014T^2 - 0.77T + 1.1e + 2$	$\beta = 0.0005T^2 - 0.1903T + 20.9699$
B 4	$\alpha = 0.0021T^2 - 1.1T + 1.6e + 2$	$\beta = 0.0010T^2 - 0.5487T + 81.0740$
B 5	$\alpha = 0.0025T^2 - 1.4T + 1.9e + 2$	$\beta = 0.0006T^2 - 0.2761T + 32.4024$
B 6	$\alpha = 0.0028T^2 - 1.4T + 1.9e + 2$	$\beta = 0.0003T^2 - 0.0217T - 12.1287$
B 7	$\alpha = 0.0033T^2 - 1.7T + 2.3e + 2$	$\beta = 0.0005T^2 - 0.0600T - 9.8584$

5.1.3. Conclusion Analysis

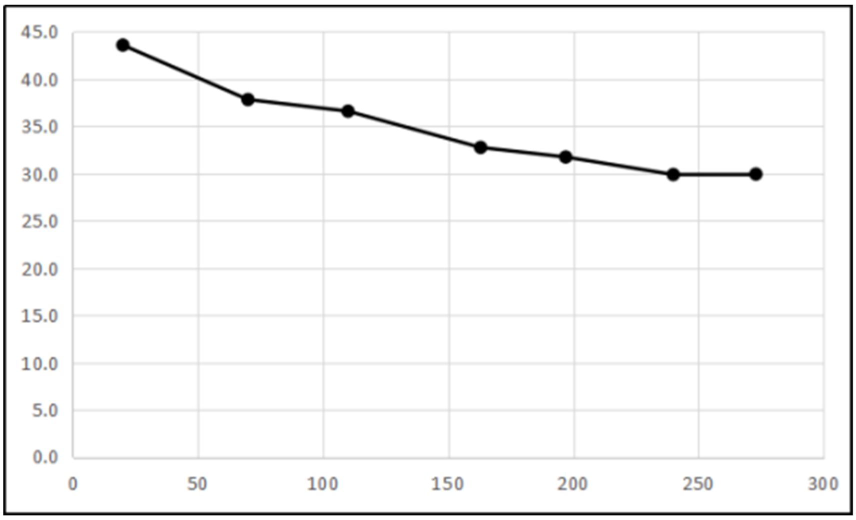


Figure 4 The relationship between ethanol conversion rate (α) and time in catalyst combination experiments given at 350 °

According to Table 1, different temperature (T) in the same catalyst combination have a great impact on the reaction performance of this experiment. Regarding the relationship between the ethanol conversion rate (α), and the temperature,(T), At the lowest value of ethanol conversion (α) at a certain temperature (), Devating from a specific temperature (T), the ethanol conversion (α) gradually increases, A2 and A7 catalysts achieve the highest ethanol conversion (α) at a certain temperature (T), Deviation from this temperature gradually decreases; Regarding the relationship between the selective (β) of the C4 olefins and the temperature (T), The lowest selectivity (β) of C4 olefins for multiple sets of catalyst combinations at a specific temperature (T), Deviation from this temperature of gradually increases, The A1, A13 catalyst combination reaches the highest value at a particular temperature (T), Deviation from this temperature of gradually decreases.

According to the analysis of the measurement value and the time of the support material 4, the time has a great influence on the experiment and a different influence on each test item. Under the same experimental conditions, the relationship between time and ethanol conversion rate (α) is inversely proportional, that is, the lower the ethanol conversion rate (α). According to the known data analysis, the selective (β) of C4 olefins reaches the lowest value at a certain time, and the second extreme point of the selective (β) reaches 200min.

5.2. Establishment and Solution of The Problem 2 Model

5.2.1. Model Establishment

In the analysis results of question 1, the 21 sets of data in Annex 1 were drawn again to obtain the influence of different temperatures on the ethanol conversion rate (α) and the selective (β) of C4 olefins in the same catalyst combination;

According to the Appendix: Noun Interpretation and Appendix Description, the variable indicators in the catalyst combination include Co loading (I), Co / SiO2, HAP loading ratio (h), and ethanol drop rate (v). According to the different result data of Annex 1 for the selective (β) of ethanol conversion rate (α) and C4 olefins caused by different catalyst combinations at the same temperature (T), a multi-way ANOVA model was adopted [4]. The significance coefficient of the relationship between Co loading (I) , Co / SiO2 and HAP loading ratio (h) and ethanol drop rate (v) and ethanol conversion rate (α) and C4 olefins selective (β), respectively, based on the influence of different catalyst combinations on the selective (β) of ethanol conversion rate (α) and C4 olefinss at the same temperature (T);

It is known that the use of the loading mode I in the catalyst experiment numbered A 1 to A 14 in Annex 1 and II in the catalyst experiment numbered B 1 to B 7. Through observation and analysis, the same groups of class A catalyst loading and catalyst loading in class B were found, and the effects of different catalyst loading on ethanol conversion (α) and C4 olefins selectivity (β) were compared at the same temperature (T) and temperature.

Using the results of the above three comparisons, the influence of the reaction condition temperature (T), Co, load (wt/%) and Co / SiO2 and HAP loading ratio (h) on the ethanol conversion rate (α) and C4 olefins selective (β) was analyzed, and then the influence of the above conditions on the reaction performance was obtained. The specific analysis flow model is as shown in Figure 5.

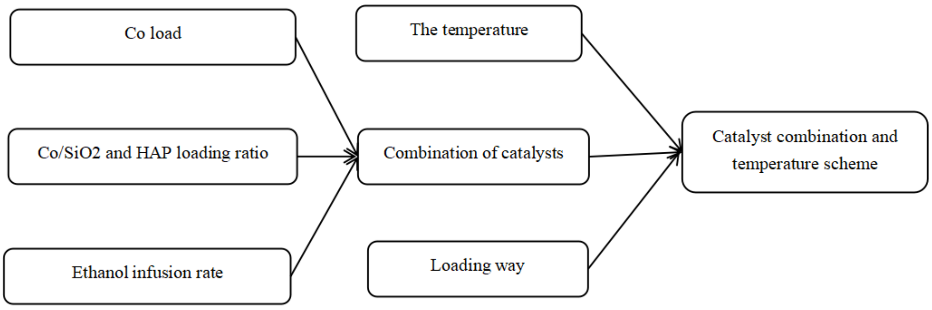


Figure 5. Problem 2 Analysis process model

5.2.2. Model Solution

(1) Different temperatures in the same catalyst combination

According to the model established by the above process, the plot function and xlsread function are called in MATLAB to mine and process the data, and the line diagram of ethanol conversion (α) and C4 olefins selectivity (β) of different temperatures (T) in the same catalyst combination are as follows, and some images are shown in FIG. 6 and supporting material 5.

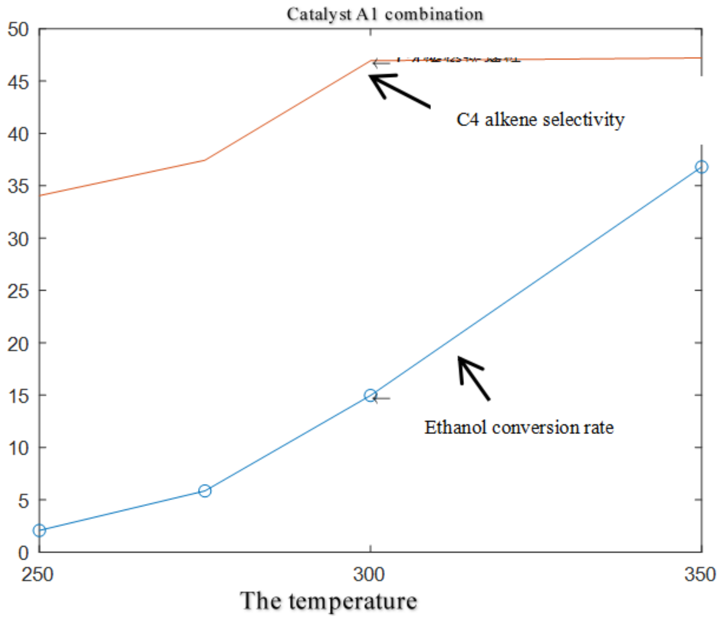


Figure 6. A1 Catalyst combined ethanol conversion rate (α), selective (β) of C4 olefins at different temperatures

According to the observation of the diagonal line chart, both the ethanol conversion rate (α) and the C4 olefins selectivity (β) are increased with the increasing temperature (T).

Different catalyst combinations at the same temperature

According to Annex 1 selective (β) results for different catalyst combinations at the same temperature (T), establish the multifactor variance significance effect on Co loading (I), Co / SiO2 and HAP loading ratio (h), ethanol drop rate (v) for ethanol conversion (α) or C4 olefins.

First, the ethanol conversion rate at the same temperature was tested for normality, and the reference data such as the mean value , the variance , and the standard deviation were calculated as follows, as shown in Table 2.$\alpha\overline{\alpha}S\,\bar{S}$

The significance value of the ethanol conversion rate (α), was 0.762 (0.000 * *), which was significant at the level and therefore did not satisfy the normal distribution.

2Table 2. Test of normality of ethanol conversion rate (α) at 250 degrees

Test of Normality	
name	Ethanol conversion rate (%)
$\bar{\alpha}$	4.826
M	2.628
S	28.893
$\bar{S}$	5.375
P	0.320
Q	19.656
scope	19.336
Quarter range	4.433
θ	1.704
μ	2.167
Shapiro — Wilk test	0.762(0.000**)
Kolmogorov Smirnov test	0.267(0.096)

Second, the homogeneity of variance test for the same ethanol conversion rate (α) at the same temperature (T), yielding the data as follows, as shown in Table 3.

3Table 3. Homogeneity of variance for ethanol conversion (α) at 250 degrees

Results of the homogeneity of variance analysis						
	The Co load quantity (wt/%)($\bar{S}_{(l)}$)				F	P
	1.0(=15)n	2.0(=2)n	0.5(=1)n	5.0(=2)n		
Ethanol conversion rate (%)	4.958	7.201	NaN	9.241	1.04	
	Co / SiO2 vs. HAP loading ratio (h)($\bar{S}_{(h)}$)				F	P
	1.0(=18)n	2.0303030303030303(=1)n	0.4925373134328358(=1)n			
Ethanol conversion rate (%)	5.581	NaN	NaN		1.312	0.295
	Ethanol drop-down rate(ml/min)($\bar{S}_{(v)}$)				F	P
	1.68(=12)n	0.3(=2)n	0.9(=3)n	2.1(=3)n		
Ethanol conversion rate (%)	3.479	3.443	2.672	1.021	0.313	0.816

According to the above table, the significance values of the ethanol conversion rate (α) were analyzed, which were not significant at the level, so the data satisfied the homogeneity of variance.

Multi-way ANOVA was performed from the data calculated above, and the results are as shown in Table 4.

4Table 4. Multivariate ANOVA on ethanol conversion rate (α) at 250 degrees

	quadratic sum	df	F	p
nodal increment	730.731	1.000	76.372	0.000
Co capacity (wt/%)	71.621	3.000	2.495	0.114
Co / SiO2 vs. HAP loading ratio (h)	1.453	2.000	0.076	0.788
Ethanol drop-down rate (ml/min)	696.368	3.000	24.260	0.000
residual	105.248	11.000	NaN	NaN

The results obtained from establishing the effect of multifactor analysis of variance on the significant effect of Co loading (I), Co / SiO2 and HAP loading ratio (h), ethanol drop rate (v) on the selective (β) of C4 olefins are detailed in Supporting Material 6.

Detailed analysis based on the above analysis results, at the same temperature (T), the Co loading (I) on the ethanol conversion (α) or C4 olefins selective (β); the Co / SiO2 and HAP loading ratio (h) on the ethanol conversion (α) or C4 olefins selective (β), and the ethanol drop rate (v) on ethanol conversion (α) or C4 olefins selective (β).

(1) Differin catalyst loading methods

According to the observation and analysis of the catalyst combination of the above model in Annex 1, it is found that the two pairs of A9 and B5, A12 and B1 have the same catalyst combination and different catalyst loading mode. The image draws the histogram as follows, see FIGS. 7 and 8, and the data are detailed in the supporting material 7.

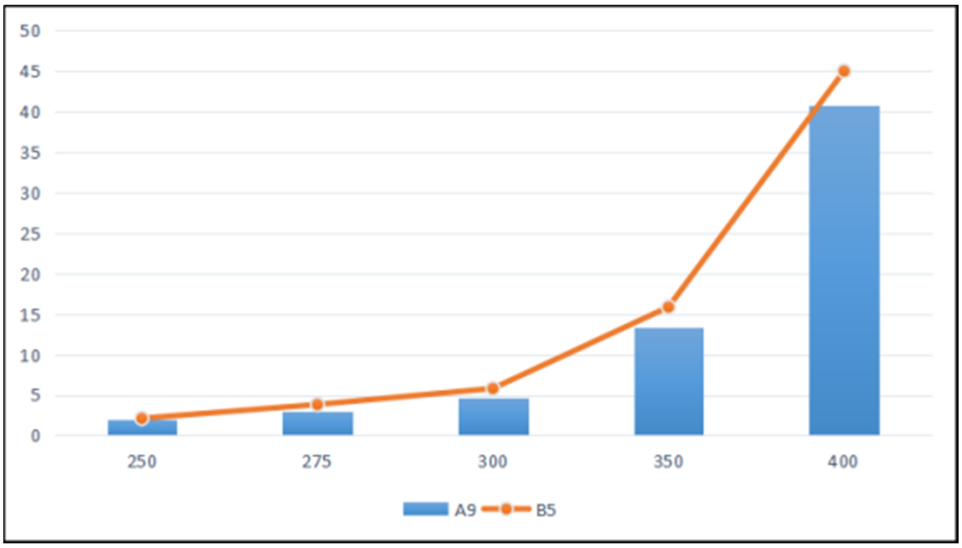


Figure 7. A9 and B5 reaction performance comparison

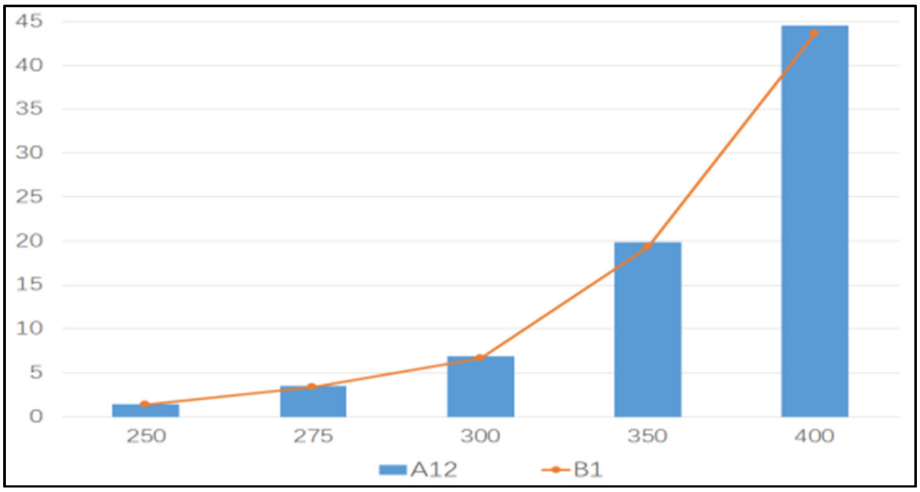


Figure 8. A12 and B1, reaction performance comparison

By observing the above two plots, the analysis shows that I and two different loading methods have little effect on the selective (β) of ethanol conversion rate (α) and C4 olefins under the same experimental conditions.

5Table 5. Multiple-factor ANOVA for the four variables

Test of Normality	
name	The C4 olefins yield (%)
$\bar{\alpha}$	2.647
M	0.769
S	21.618
$\bar{S}$	4.649
P	0.007
Q	26.541
scope	26.534
Quarter range	2.930
θ	3.070
μ	10.762
Shapiro — Wilk test	0.592(0.000***)
Kolmogorov Smirnov test	0.285(0.000***)

	The Co load quantity (I)($\bar{S}_{(I)}$)				F	P
	1.0(=60)n	2.0(=8)n	0.5(=4)n	5.0(=8)n		
The C4 olefins yield (%)	3.741	8.749	7.567	2.018	3.999	0.011 *

	Co / SiO2 vs. HAP loading ratio (h)($\bar{S}_{(h)}$)			F	P
	1.0(=72)n	2.0303030303030303(=4)n	0.4925373134328358(=4)n		
The C4 olefins yield (%)	4.848	1.601	1.217	1.306	0.277

	Ethanol drop-down rate (v)($\bar{S}_{(v)}$)				F	P
	0.3(=8)n	0.9(=12)n	2.1(=12)n	1.68(=48)n		
The C4 olefins yield (%)	3.669	5.288	1.268	5.100	1.771	0.160

	Ttemperature(T)($\bar{S}_{(T)}$)				F	P
	275(=20)n	300(=20)n	350(=20)n	250(=20)n		
The C4 olefins yield (%)	0.819	2.238	6.925	0.310	18.505	0.000 ***

Multiway ANOVA results				
	quadratic sum	df	F	p
nodal increment	0.105	1.000	0.009	0.925
Co capacity (I)	65.302	3.000	1.838	0.149
Co / SiO2 vs. HAP loading ratio of (h)	38.177	2.000	1.611	0.207
Ethanol drop-down rate (ml/min)	114.362	3.000	3.218	0.028
temperature (T)	442.293	3.000	12.445	0.000
residual	805.537	68.000	NaN	NaN

5.2.3. Conclusion Analysis

Based on the effects of different catalyst combinations and temperature (T) on the selectivity (β) of ethanol conversion rate (α) and C4 olefins, the literature is reviewed[3] . It can be seen that the load amount of Co is adjusted according to the loading ratio (h) of Co / SiO2 and HAP to ensure that the surface acid and alkalinity of the catalyst are suitable for the experiment.

Therefore, comprehensive analysis shows that under the same condition of other experimental conditions, the ethanol conversion rate (α), temperature (T) and ethanol infusion rate (v) have a greater impact on its size, while the Co loading rate (I) and the Co/SiO2 and HAP loading ratio (h) have a smaller impact on its size. Regarding the selectivity of C4 olefin (β), temperature (T) and Co loading (v) have a greater impact on it, while the Co/SiO2 and HAP loading ratio (h) and ethanol dripping rate (v) have a smaller impact on its size.

5.3. Establishment and Solution of Problem 3 Models

5.3.1. Model Establishment

The value of C4 olefin yield (δ) is equal to the product of ethanol conversion (α) and C4 olefin selectivity (β). According to the data in Annex 1, the influence degree of temperature (T), Co loading (I), Co/SiO2 and HAP loading ratio (h) and ethanol dripping rate (v) on C4 olefin yield (δ) was modeled and analyzed. Multivariate analysis of variance model [4] and weight analysis were used to analyze the above four independent variables. The influence degree ranking of four independent variables on C4 olefin yield (δ) was obtained.

A hierarchical regression model [5] was established according to the effects of temperature (T), Co loading (I), Co/SiO2 and HAP loading ratio (h) and ethanol dripping rate (v) on C4 olefin yield (δ), and the fitting effect diagram was analyzed and drawn. Finally, a linear regression model was established to construct a functional model with temperature (T), Co loading (I), Co/SiO2 and HAP loading ratio (h), ethanol dripping rate (v) as independent variables and C4 olefin yield (δ) as dependent variable, and the coefficients were calculated.

Finally, through the above analysis and function construction, the catalyst combination and temperature (T) were developed to make the C4 olefin yield (δ) as high as possible; And analysis of the temperature (T) below 350 degrees, making C4 olefin yield (δ) as high as possible catalyst combination and temperature (T).

5.3.2. Model Solution

(1) Multiple-factor ANOVA and weight analysis

By analogy with the construction of multivariate analysis of variance model in 5.2.2, it was analyzed and discussed, and the effects of temperature (T), Co loading (I), Co/SiO2 and HAP loading ratio (h), and ethanol dripping rate (v) on C4 olefin yield (δ) were ranked. The results are as follows, as shown in Table 5.

The results obtained by weight analysis are as follows, shown in Table 6.

6Table 6. Weight analysis of the four variables

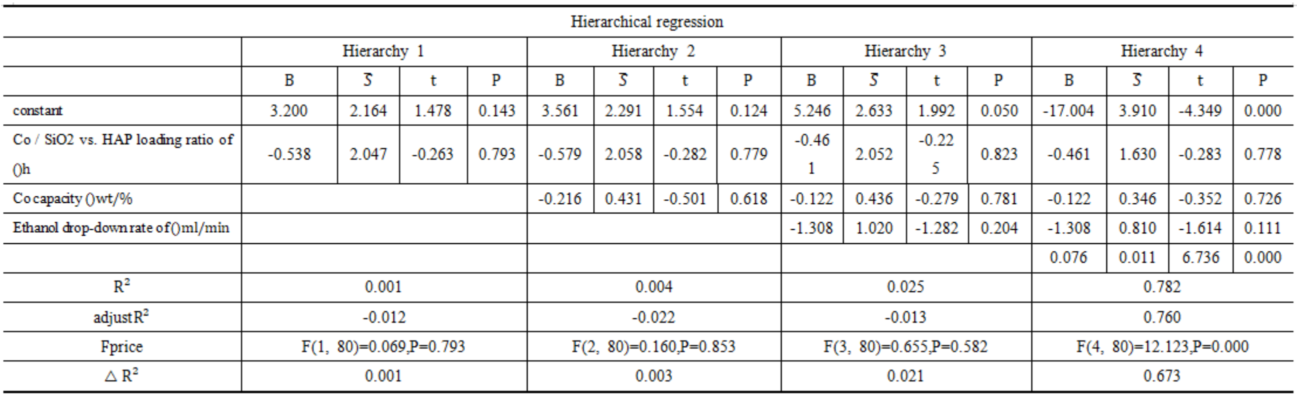
Feature name	weight
h	0.0000
l	0.0764
v	0.2244
T	0.6992

According to the analysis in the above table, four independent variables can be obtained to rank the influence degree of C4 olefin yield (δ): temperature (T)> ethanol dripping rate (v)>Co loading rate (I)>Co/SiO2 and HAP loading ratio (h).

(2) Hierarchical regression

The conclusion analysis at the above level is based on a hierarchical regression model. The results of the analysis of the difference value test result (F) are as follows, shown in Table 7.

7Table 7. Results analysis of the hierarchical regression models



Hierarchical regression																
	Hierarchy 1				Hierarchy 2				Hierarchy 3				Hierarchy 4			
	B	S̅	t	P	B	S̅	t	P	B	S̅	t	P	B	S̅	t	P
constant	3.200	2.164	1.478	0.143	3.561	2.291	1.554	0.124	5.246	2.633	1.992	0.050	-17.004	3.910	-4.349	0.000
Co / SiO2 vs. HAP loading ratio of ()h	-0.538	2.047	-0.263	0.793	-0.579	2.058	-0.282	0.779	-0.461	2.052	-0.225	0.823	-0.461	1.630	-0.283	0.778
Co capacity ()wt/%					-0.216	0.431	-0.501	0.618	-0.122	0.436	-0.279	0.781	-0.122	0.346	-0.352	0.726
Ethanol drop-down rate of()ml/min									-1.308	1.020	-1.282	0.204	-1.308	0.810	-1.614	0.111
													0.076	0.011	6.736	0.000
R^2	0.001				0.004				0.025				0.782			
adjustR^2	-0.012				-0.022				-0.013				0.760			
Fprice	F(1, 80)=0.069,P=0.793				F(2, 80)=0.160,P=0.853				F(3, 80)=0.655,P=0.582				F(4, 80)=12.123,P=0.000			
△R^2	0.001				0.003				0.021				0.673			

R^2 According to the above table, the fit of the stratified models of the various independent variables was analyzed by the values, and the fitting effects were drawn as follows, as shown in Figure 9.

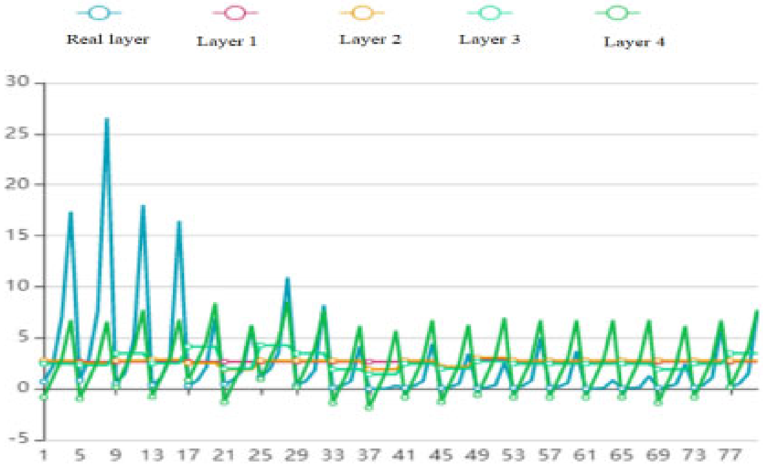


Figure 9. Fitting effects of the hierarchical regression

(3) linear regression

Using the above two conclusions analysis, linear regression models were constructed using temperature (T), Co loading (I), Co / SiO2 and HAP loading ratio (h) and drop rate (v) of ethanol as independent variables, and the results are as follows, as shown in Table 8.

8Table 8. Results of the analysis of the linear regression models

Linear regression analysis results =80n

	Non-standardized coefficients		Standardization coefficient	tBeta	p	VIF	R^2	adjustR^2	F
	B		standard error						
constant	-17.004		3.910	-	-4.349	0.000***	-		
constant	-17.004	3.910	-	-4.349	0.000***	-	0.782	0.760	FP=12.123 =0.000***
Co capacity ()wt/%	-0.122	0.346	-0.032	-0.352	0.726	1.031			
Co / SiO2 vs. HAP loading ratio of ()h	-0.461	1.630	-0.025	-0.283	0.778	1.004			
Ethanol drop-down rate was ()ml/min	-1.308	0.810	-0.147	-1.614	0.111	1.031			
temperature ()T	0.076	0.011	0.606	6.736	0.000***	1.000			

Building the function model from the table above and calculating its coefficients, obtaining the function,

$$\delta = -17.004 - 0.122 \cdot \mathrm{l} - 0.461 \cdot \mathrm{h} - 1.308 \cdot \mathrm{v} + 0.076 \cdot \mathrm{T}$$

5.3.3. Conclusion Analysis

According to the above analysis process and conclusion, combined with the conclusion of problem two, it is not difficult to analyze that under the same experimental conditions when the catalyst combination is A2, that is, 200mg 2wt%Co/SiO2- 200mg HAP-ethanol concentration of 1.68 catalyst combination, temperature (T) is 350 degrees when the C4 olefin yield (δ) is as high as possible; If the temperature (T) is lower than 350 degrees, the catalyst combination is still A2, and the C4 olefin yield (δ) is as high as possible when the temperature (T) is 300 degrees.

5.4. Establishment and Solution of The Problem Four Models

5.4.1. Model Establishment

Based on the comprehensive analysis of the known catalyst combination and temperature scheme in Annex 1, and based on the model establishment, analysis and solution of the previous three questions, five new experimental catalyst combination and temperature scheme are formulated for the purpose of improving the accuracy of experimental data and enhancing the reliability of the above conclusions.

As the data given in Annex 1 are sufficient to prove that temperature has A great influence on the reaction performance of the experiment, the catalyst combination scheme divided according to the support material 1 is supplemented by the catalyst combination scheme of group A in the catalyst charging method I, and that of group B in the catalyst charging method II.

Combined with the conclusions in question 3: temperature (T) > ethanol indoctrination rate (v) > Co loading rate (I) > Co/SiO2 and HAP loading ratio (h), comprehensive analysis suggests that it is necessary to supplement and verify the relevant experimental comparison groups on the effects of ethanol indoctrination rate (v), Co loading rate (I), Co/SiO2 and HAP loading ratio (h) on the experimental reactivity.

5.4.2. Model Solution

(1) The drip rate of ethanol

9Table 9. Scheme of catalyst combination and temperature of group B 8

group	Control group	Catalyst combination	temperature
B8	A7	50mg 1wt%Co / SiO250mg HAP-ethanol concentration of 0.3ml / min	250
			275
			300
			350

The catalyst combination plan of group A and group B was compared and analyzed, and the experimental group lacking ethanol infusion rate (v) of group B was found to be 0.3.ml/min. The actual catalyst combination and temperature plan are as follows, as shown in Table 9.

(2) Co load amount

By comparing with the above analysis methods, it can be concluded that group B lacks the experimental group with Co loading (I) as 0.5wt/%, 2wt/%, and 5wt/%. The actual catalyst combination and temperature scheme are as follows, as shown in Table 10.

10Table 10. Scheme of catalyst combination and temperature of groups B 9, B10 and B11

group	Control group	Catalyst combination	temperature
B9	A4	The concentration of 200 m g of 0.5 w t% C o / SiO2200mg HAP-ethanol was 1.68ml / min	250
			275
			300
			350
B10	A5	The 200mg 2wt%Co / SiO2200mg HAP-ethanol concentration was 0.3ml / min	250
			275
			300
			350
B11	A6	200mg 5wt%Co / SiO2200mg HAP-ethanol was 1.68ml / min	250
			275
			300
			350

(3) Co/SiO2And HAP loading ratio

According to the above analysis method, group B lacks the experimental group with Co / SiO2 and HAP loading ratio (h) of 33mg:67mg. The actual catalyst combination and temperature scheme are as follows, as shown in Table 11.

11Table 11. Scheme of catalyst combination and temperature of group B 12

group	Control group	Catalyst combination	temperature
B12	A14	33mg 1wt%Co / SiO267mg HAP-ethanol concentration was 1.68ml / min	250
			275
			300
			350

5.4.3. Conclusion Analysis

According to the scheme of catalyst combination and temperature in the model solution, the experimental data can be compared with the control group to verify the influence of the ethanol drop rate (v), Co loading (I) , Co / SiO2 and HAP loading ratio (h) on the reaction performance of the experiment, once again to verify the conclusion analysis of the previous three questions, and improve the reliability of the experimental data.

6. Evaluation and Generalization of The Model

6.1. Advantages of the Model

The model is simple and understandable in content. Through the multivariate factor ANOVA of multiple reaction conditions (independent variables), the degree of significant influence of each reaction condition on the reaction performance can be obtained. Individual reaction conditions were hierarchical stratified by hierarchical regression model to analyze the optimal solution for different reaction conditions.

The model is easy to operate. MATLAB can be used to conduct model building, data mining, processing, so as to use the model to obtain the problem results.

The problem between the model is closely related. The appropriate problem-solving model can be selected according to different independent variables.

The model is universal under different conditions. In a variety of environmental contexts, this model can easily obtain the key parameters in the model according to some data. By changing the parameters, the model can play in different environments.

6.2. Disadvantages of the Model

The hierarchical data of this model may be quite different, leading to completely accurate model results.

6.3. Extension of the Model

The model is based on a hierarchical regression model to study the reaction performance of coupling prepared C4 olefins, which can be optimized by modifying multiple independent variables, making the model applicable to the problem study of different multiple independent variables to a single dependent variable.

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