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Yarn Quality influenced by Drafting Parameters.

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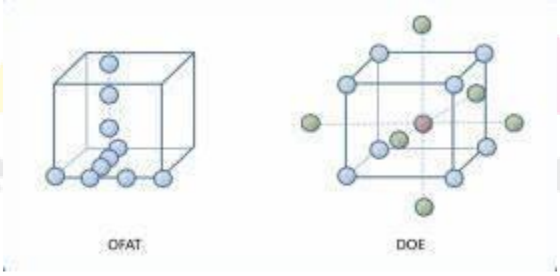
Abstract:

This study aimed to refine ring spinning by optimizing drafting factors. We tested three parameters at varying levels: break draft, pin spacer size, and rubber cots hardness. Among these, pin spacer size significantly impacted yarn quality, improving attributes like evenness, imperfections, hairiness, and strength. Larger spacer sizes reduced fiber cohesion during drafting, enhancing the transfer of individual fibers to create a more integrated yarn structure and better overall quality.

Keywords: cotton fibre, normal spinning, break draft, spacer size, cots shore hardness, U%, Cv m%, 10 M cv%, CSP, Elongation, Hairiness level, Cronbach's Alpha, correlation matrix , response surface regression , factorial plots , contour plots , regression equationsCo-efficient of determination r^2 , factorial interaction plots

Introduction:

Normally in textiles spinning we use to conduct lots of experiments by varying one factor at a time (OFAT) and study its impact on the output or responsible variables. But often this kind of approach miss out the interaction happening between various inputs factors on response variable. We are accounting for those interactions which is shown in regression equations and contour plots.



An interaction effect refers to the combined influence of two or more independent variables (factors) on the dependent variable (response) that is not simply additive. When these factors interact, their combined effect on the response variable is different from what would be expected by considering each factor's individual effects independently.

Response surface regression aims to model the relationship between multiple independent variables and a response variable that might not have a linear relationship. It's especially useful when trying to optimize a process or understand complex interactions among variables.

Interaction effects in response surface regression become crucial because they signify situations where the effect of one variable on the response depends on the level or value of another variable. This means that the impact of changing one variable may differ based on the value of another variable. These interactions are often visualized using response surface plots, which depict how the response changes as two or more variables simultaneously vary.

Identifying and understanding these interaction effects are essential for accurately modelling and predicting the response variable. It helps in optimizing processes by highlighting how adjustments in different variables can lead to varying outcomes based on their combined effects.

Ring spinning stands out as a top method for yarn production, delivering superior yarn properties. Yet, its efficiency faces limitations like slower traveller speed, high tension, and lower spindle speed compared to other spinning systems. Despite lower productivity, ring spinning creates yarn with excellent mechanical qualities.

The process involves drafting, twisting, and winding. Drafting, especially, influences yarn quality significantly. Previous studies have explored various drafting parameters to enhance yarn quality in spinning systems. Parameters like drafting angle, spinning triangle, draft amount, roller settings, rubber hardness, and spacer characteristics all impact yarn quality.

This work aims to optimize ring spun yarn's technological parameters using a response surface regression analysis, factorial, and contour plot design. Specifically, we focused on three drafting parameters: break draft, hardness of the top front roller, and pin spacer size. The pin spacer, categorized by size, serves to maintain space between aprons for fiber assembly in the drafting zone. It not only fulfils this basic function but also provides additional support to the drafted fiber assembly, resulting in structurally sound yarn. Determining the ideal pin spacer size for the desired yarn density poses a challenge, making it a crucial factor in this study—a novel exploration in optimizing the ring spinning process.

Cotton Material details:

Cotton Parameter	Mean		SD
Elongation %	7.161	±	6.7
Fineness (mtex)	149.11	±	1.52
Length (mm)	26.75	±	1.1
Maturity Index	0.796	±	0.037
Moisture (%)	6.002	±	0.43
Reflectance (Rd)	71.495	±	0.83
Short Fiber Index	7.703	±	0.93
Strength (cN/tex)	30.465	±	0.92
Uniformity Index	79.542	±	0.95
Yellowness (+b)	8.13	±	0.042

Output material:

30s Carded knitting was made with 0.80 Ne rove hank at 20,400 Rpm with 24.1 TPI at normal spinning**.**

Definitions of chosen factors:

Berak Draft:

It refers to the draft applied to the fibers between the back roller and the apron pair in aspinning frame.

The primary purpose of break draft is to control the tension and elongation of the fibers as they pass through the main drafting zone. By applying a certain level of draft, the fibers are attenuated and elongated gradually, reducing the possibility of sudden tension variations that could cause yarn breakage or quality issue.

Break draft is adjusted based on various factors like the type of fibers being spun, their fineness, and the desired characteristics of the final yarn. It's crucial to strike a balance between providing enough elongation to the fibers for proper spinning and preventing excessive tension that could lead to breaks or imperfections in the yarn.

Cots shore Hardness:

The Shore hardness of cots refers to a measurement of the surface hardness of the rubberor elastomeric material used in the roller covering within a spinning machine. Cots are essential components in the drafting system of spinning machines, responsible for gripping and guiding the fibers as they are drawn into yarn.

The Shore hardness is measured using a durometer and is expressed as a numerical value. There are different scales for Shore hardness, such as Shore A and Shore D, commonly used to assess the hardness of rubber and elastomeric materials.

For cots used in spinning, Shore hardness is crucial because it determines the surface characteristics and contact mechanics of the cots with bottom roller or drum under top arm loading:

Cots with a higher Shore hardness will have a harder surface. They might offer better wearresistance and durability but might be less flexible. Whereas Lower Shore hardness will have a softer surface, which might provide better fiber grip and conformity but could be more prone to wear and tear.

The choice of the Shore hardness for cots depends on various factors, including the type of fibers being processed, the spinning conditions, and the desired quality of the final yarn. Different spinning processes and fibers might require different hardness levels to ensure optimal performance and yarn quality.

Pin spacer:

The pin spacer plays a crucial role in the double apron drafting system. It is a small element that decides the spacing between the two aprons in the front drafting zone in ring frame. The pressure between the aprons in the drafting zone is controlled by the spacer, which governs the degree of control exercised on the floating fibers and ultimately.

A typical pin spacer

has an influence over the drafting irregularities. If the spacer is too narrow, it disturbs the smooth fiber flow, and if the space is too wide, then the fibers move in the drafting zone in an uncontrolled manner. Both cause an increase in unevenness and imperfections. Hence, the spacing between two aprons should be optimized by proper selection of spacers.

Experimental factors and their levels.

Factor selected	Actual values assigned	
	Low level	High level
Break Draft	1.28	1.34
Cots shore Hardness	63	68
Pin Spacer Size (mm)	3.00	3.50

Data summary:

Explanatory variable or Factors			Response value which is Physical Properties of Yarn					
X_1	X_2	X_3	Y1	Y2	Y3	Y4	Y5	Y6
BD	Spacer size	Cots Hardness	U%	CVm%	10m Cv	H	IPI/km	CSP
1.28	3.0	63	12.66	15.25	2.58	6.00	692.95	2242.30
1.34	3.0	63	12.61	15.51	2.59	6.13	661.27	2152.21
1.28	3.5	63	11.62	13.96	2.47	5.44	466.24	2385.85
1.34	3.5	63	11.98	15.34	2.45	5.49	445.45	2396.74
1.28	3.0	68	12.83	15.29	2.72	5.99	715.72	2255.17
1.34	3.0	68	13.23	16.04	2.66	6.07	872.14	2171.02
1.28	3.5	68	11.77	15.14	2.61	5.62	368.23	2317.54
1.34	3.5	68	11.99	15.07	2.59	5.54	486.04	2325.46

Correlation study among outcome or response variables:

Correlations	U	CVm	10m	H	IPI
CVm	0.770				
10m	0.691	0.537			
H	0.909	0.680	0.686		
IPI	0.968	0.617	0.609	0.865	
CSP	-0.849	-0.689	-0.677	-0.957	-0.816

-1 = Strongly negative correlation, 0 = No correlation, +1 Strong positive correlation

Model reliability:

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items
.018	.670

Cronbach's Alpha is a measure used to assess the internal consistency or reliability of a scale or a set of items that are intended to measure the same underlying construct.

When Cronbach's Alpha is calculated based on standardized items, it means that the analysis is conducted using standardized scores of the items rather than the raw scores. Standardizing involves transforming the scores of each item to a common scale with a mean of 0 and a standard deviation of 1.

Calculating Cronbach's Alpha based on standardized items can be useful in certain cases,especially when the items in the scale have different measurement units or scales.Standardization helps in putting all the items on a comparable scale, allowing for a more direct comparison of their contributions to the overall reliability of the scale.

In our case the input factors and response variables doesn't have the same UOM or unit of measurement for instance Hairiness unit , CSP and IPI and spacer size in mm are all different scale of measurements so we must use Cronbach's Alpha Based on Standardized Items which is around 0.67 It's notably higher than the non-standardized Cronbach's Alpha, indicating a better level of internal consistency when the items are standardized. A value of 0.670 might still be considered moderate and not yet ideal for many research purposes but is an improvement compared to the non-standardized version. This must be noted as still in the model there may be noise and other factors influencing the responsive variable unexplained by input factors.

Response screening by JMP pro:

Y	Factors	F ratio	P value	Log worth	FDR P value	FDR Log worth	Rank Fraction	Df
U%	Break Draft	3.870	0.121	0.919	0.217	0.664	0.556	1.000
U%	Pin Spacer size	70.519	0.001	2.958	0.008	2.111	0.111	1.000
U%	Cot's hardness	4.038	0.115	0.940	0.217	0.664	0.500	1.000
Cv m%	Break Draft	4.402	0.104	0.983	0.217	0.664	0.444	1.000
Cv m%	Pin Spacer size	5.444	0.080	1.097	0.206	0.687	0.389	1.000
Cv m%	Cot's hardness	1.791	0.252	0.599	0.378	0.423	0.667	1.000
10 M Cv%	Break Draft	2.189	0.213	0.671	0.349	0.458	0.611	1.000
10 M Cv%	Pin Spacer size	49.973	0.002	2.675	0.010	2.022	0.222	1.000
10 M Cv%	Cot's hardness	64.892	0.001	2.890	0.008	2.111	0.167	1.000
Hairiness H	Break Draft	0.695	0.451	0.346	0.497	0.304	0.889	1.000
Hairiness H	Pin Spacer size	94.635	0.001	3.204	0.008	2.111	0.056	1.000
Hairiness H	Cot's hardness	0.549	0.500	0.301	0.500	0.301	1.000	1.000
Total IPI / Km	Break Draft	1.010	0.372	0.430	0.478	0.321	0.778	1.000
Total IPI / Km	Pin Spacer size	28.423	0.006	2.225	0.021	1.668	0.278	1.000
Total IPI / Km	Cot's hardness	0.638	0.469	0.329	0.497	0.304	0.944	1.000
CSP	Break Draft	1.449	0.295	0.530	0.409	0.389	0.722	1.000
CSP	Pin Spacer size	21.946	0.009	2.026	0.028	1.549	0.333	1.000
CSP	Cot's hardness	0.698	0.450	0.346	0.497	0.304	0.833	1.000

Factors: The factors being analysed are "Break Draft," "Pin Spacer size," and "Cot's hardness,". These factors are related to measurements denoted by "U%," "Cv m%," "10 MCv%," "Hairiness H," "Total IPI / Km," and "CSP."

F-ratio and P-value: The F-ratio measures the ratio of variance between groups to variance within groups. A low p-value (typically below a significance threshold like 0.05) indicates that there is evidence to reject the null hypothesis for that factor, suggesting a significant relationship with the measured variables.

Log Worth: Log worth signifies the strength of association or effect size between factors and the measured variables.

FDR-adjusted P-value and FDR Log Worth: These columns likely present adjusted p- values and log worth after controlling for False Discovery Rate (FDR). The FDR adjustment helps mitigate the risk of false positives in multiple comparisons.

Rank Fraction and Df: Rank fraction could indicate the ranking of the factors based on their significance or effect size. Df typically refers to degrees of freedom, crucial in statistical hypothesis testing.

Inference:

Factors (like "Pin Spacer size" and "Hairiness H") seem to have lower p-values, indicating a significant relationship with the measured variables. The FDR-adjusted p-values (FDR P value) also show significance for certain factors even after controlling for multiple comparisons. Factors like "Pin Spacer size" and "Hairiness H" consistently demonstrate higher log worth and FDR log worth, indicating stronger associations with the measuredvariables.

Now we shall Model the observed data by using Minitab 19 response surfacemethodology:

We will be using response surface regression which is a statistical technique used to model the relationship between multiple variables and a response of interest. It's particularly valuable in understanding complex interactions between variables and how they impact an outcome. Instead of relying on a simple linear model, response surface regression explores nonlinear relationships, allowing for the analysis of intricate processes and their effects.

This method involves fitting a mathematical equation to experimental data to predict how changes in input variables affect the response variable. By plotting the surface generated by this equation, analysts can visualize the relationship between multiple factors and the response, identifying optimal conditions or regions that yield the desired outcome.

Response Surface Regression: CSP versus BD, Spacer size, Cots Hardness

Coded Coefficients

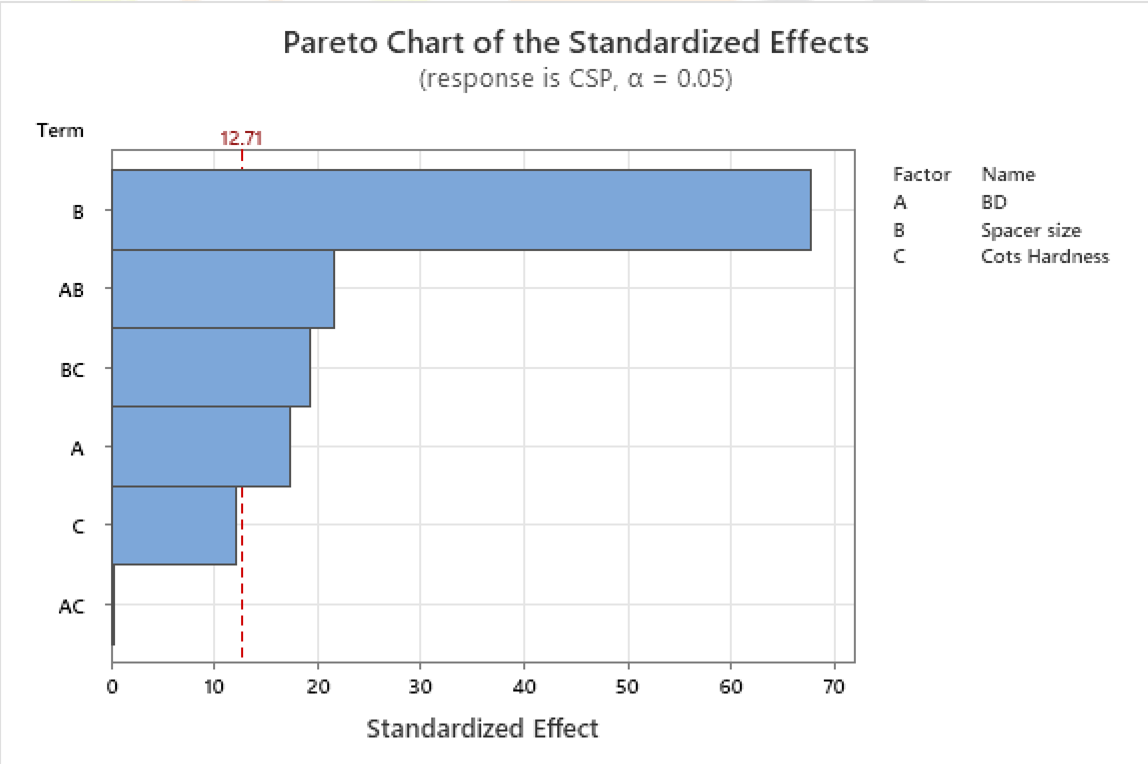
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2280.79	1.11	2047.84	0.000	
BD	-19.43	1.11	-17.44	0.036	1.00
Spacer size	75.61	1.11	67.89	0.009	1.00
Cots Hardness	-13.49	1.11	-12.11	0.052	1.00
BD*Spacer size	24.13	1.11	21.67	0.029	1.00
BD*Cots Hardness	0.37	1.11	0.33	0.795	1.00
Spacer size*Cots Hardness	-21.41	1.11	-19.22	0.033	1.00

Model Summary

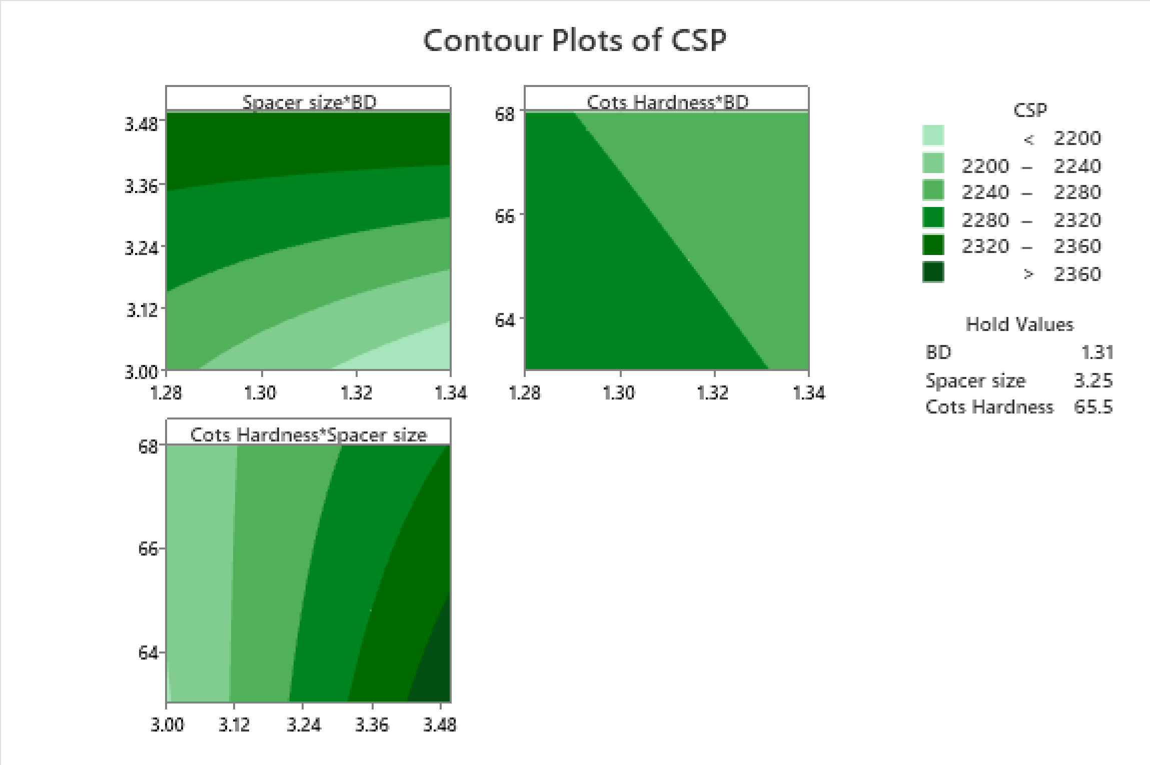
S	R-sq	R-sq(adj)	R-sq(pred)
3.15016	99.98%	99.88%	98.92%

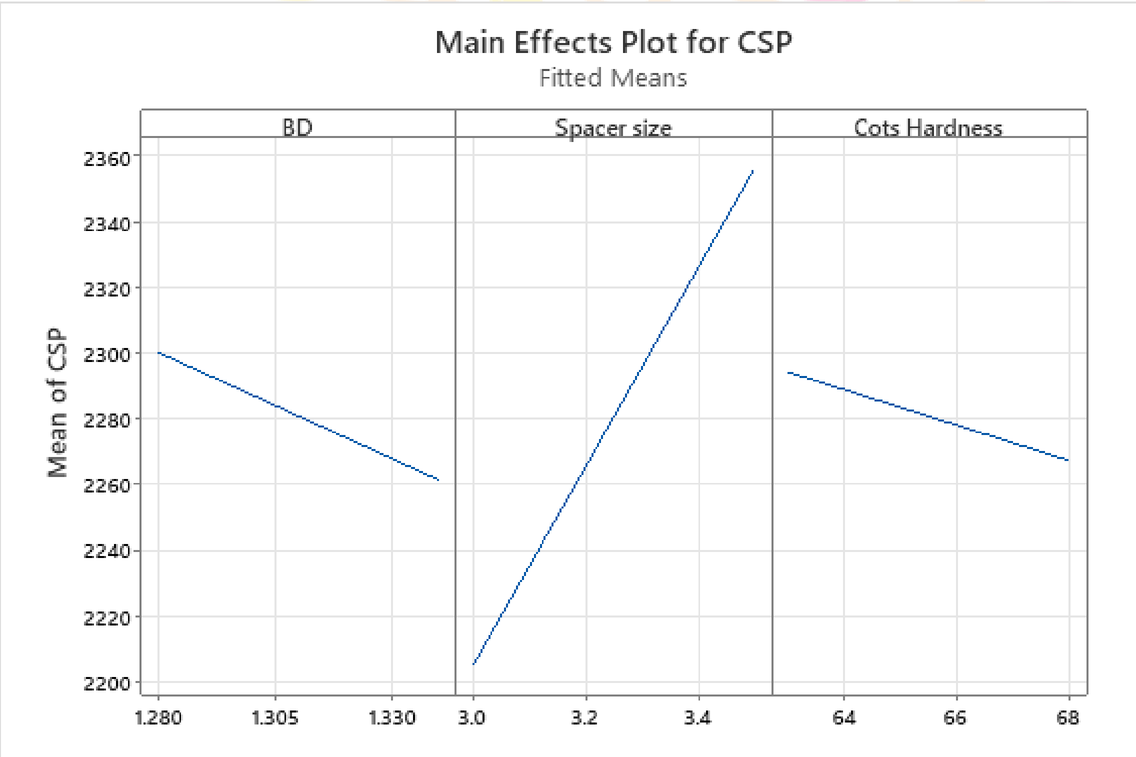
Regression Equation in Uncoded Units

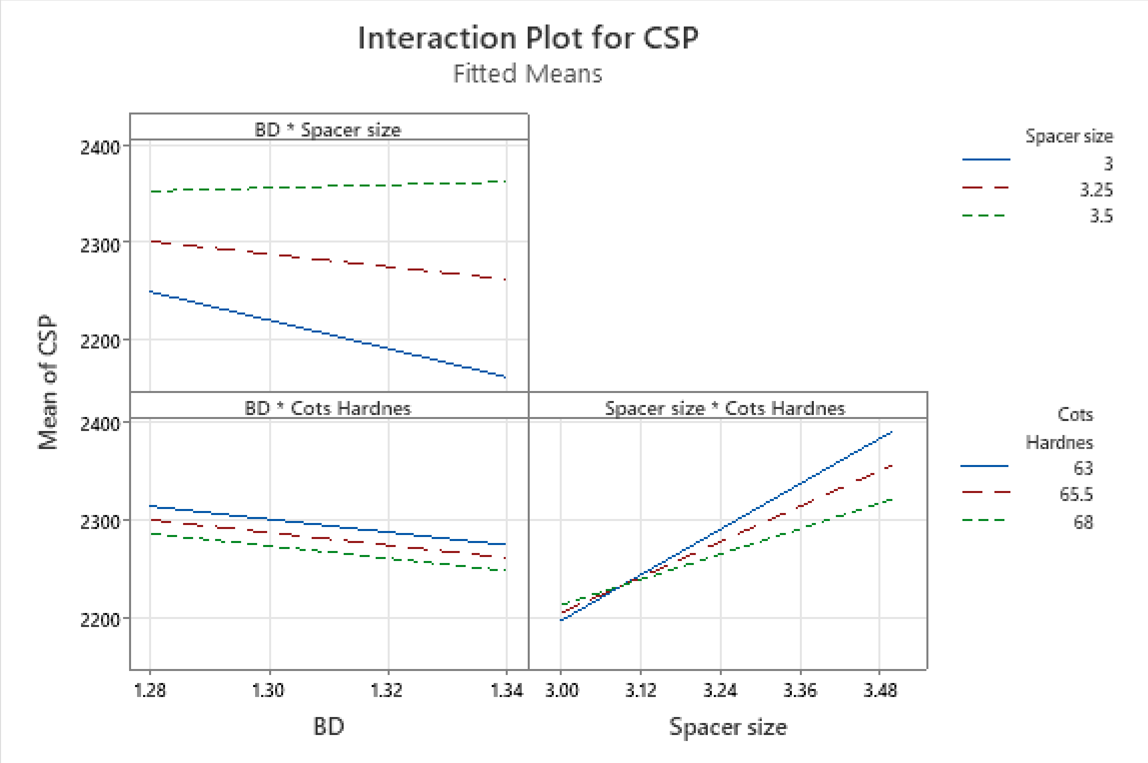
CSP = 9331 - 11429 BD - 1669 Spacer size + 99.4 Cots Hardness + 3218 BD*Spacer size + 4.9 BD*Cots Hardness - 34.25 Spacer size*Cots Hardness



Inference on CSP: BD and spacer size, spacer size and cots hardness are interacting verysignificantly which must be noted from trial point of view.


Contour Plots of CSP
Spacer size*BD
Cots Hardness*BD
Cots Hardness*Spacer size
CSP
< 2200
2200 – 2240
2240 – 2280
2280 – 2320
2320 – 2360
> 2360
Hold Values
BD 1.31
Spacer size 3.25
Cots Hardness 65.5


Main Effects Plot for CSP
Fitted Means
BD
Spacer size
Cots Hardness
Mean of CSP



Inference: strong interactions is happening especially spacer size and cots hardness sincethose are having different slopes thus no parallel to each other.

Response Surface Regression: CVm% versus BD, Spacer size, Cots HardnessCoded Coefficients

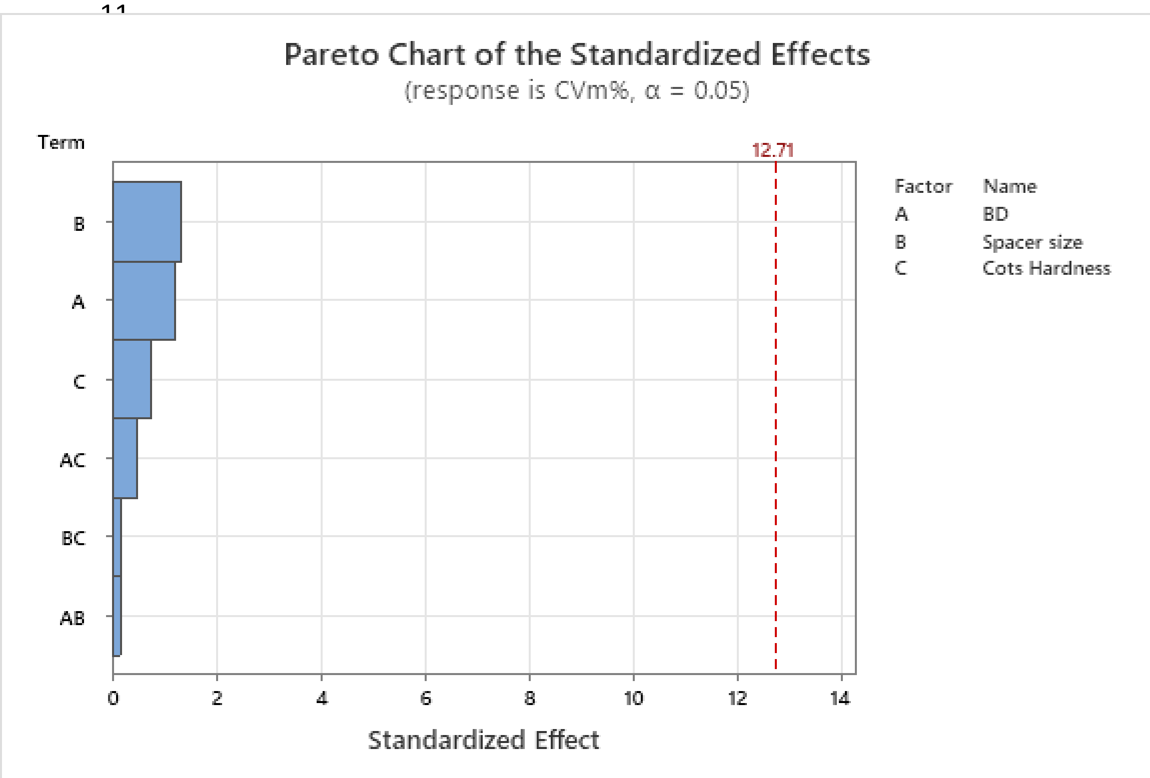
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	15.200	0.242	62.68	0.010	
BD	0.290	0.242	1.20	0.443	1.00
Spacer size	-0.322	0.242	-1.33	0.410	1.00
Cots Hardness	0.185	0.242	0.76	0.585	1.00
BD*Spacer size	0.037	0.242	0.15	0.902	1.00
BD*Cots Hardness	-0.120	0.242	-0.49	0.707	1.00
Spacer size*Cots Hardness	0.043	0.242	0.18	0.890	1.00

Model Summary

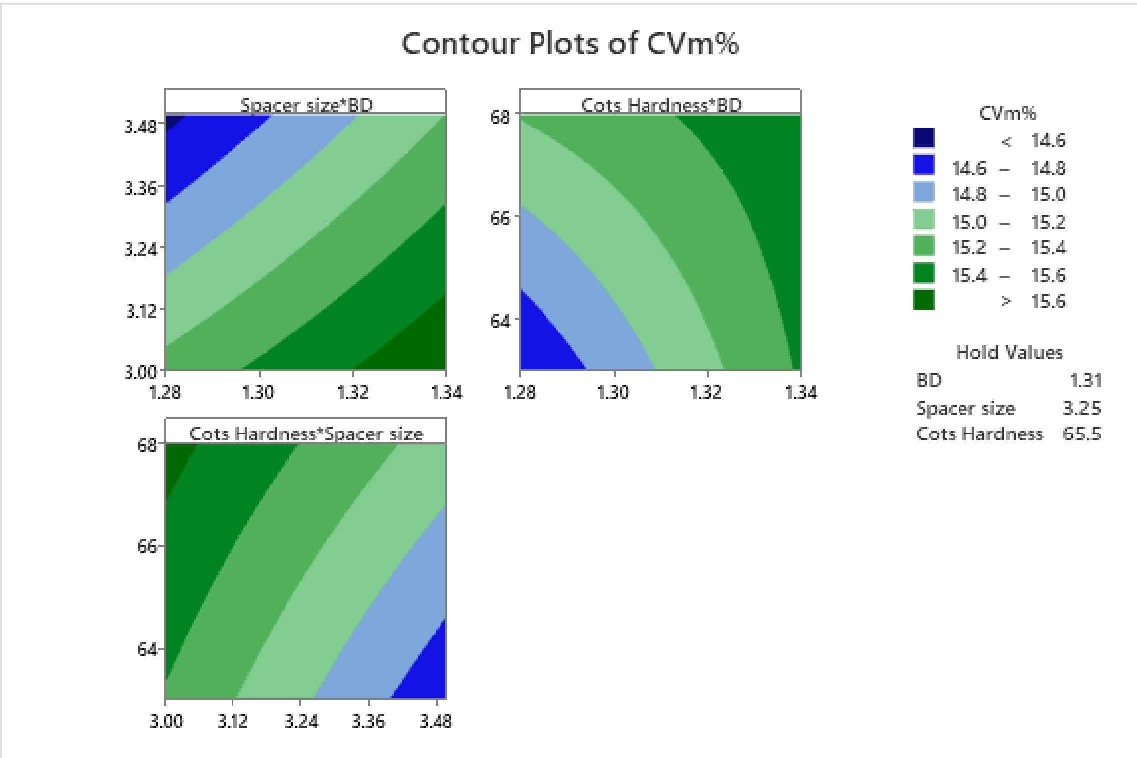
S	R-sq	R-sq(adj)	R-sq(pred)
0.685894	80.32%	0.00%	0.00%

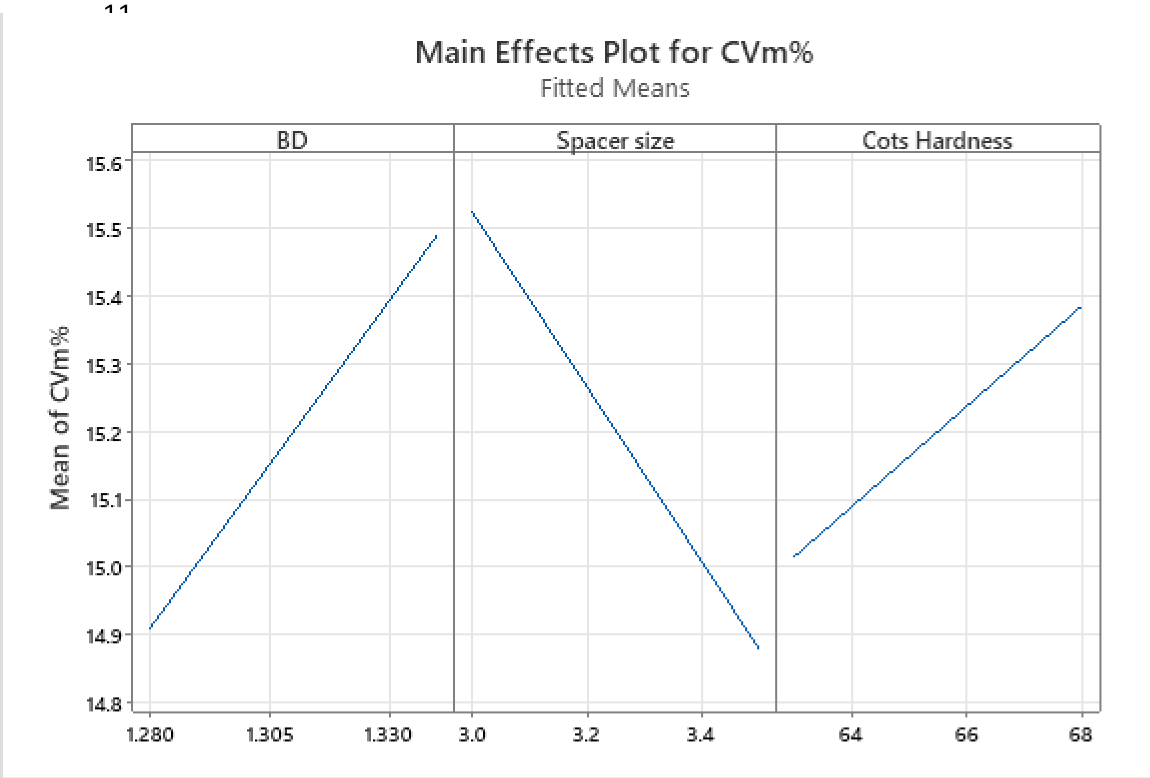
Regression Equation in Uncoded Units

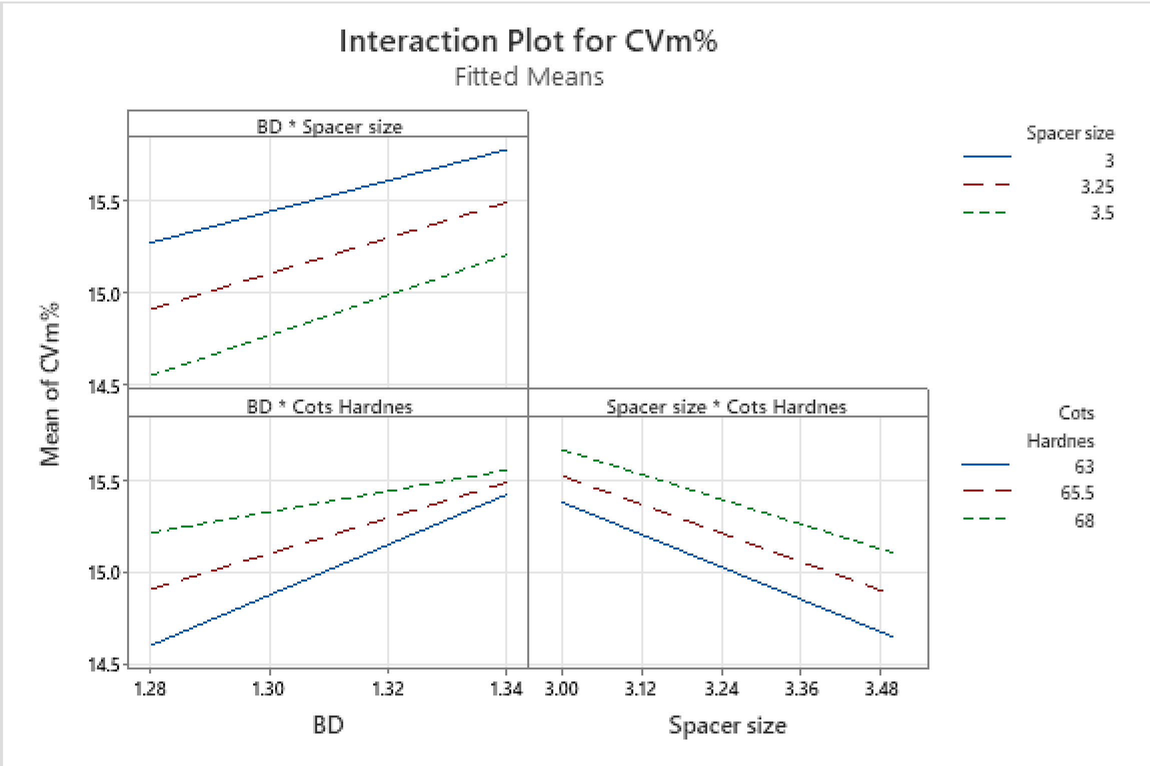
CVm% = -100 + 98 BD - 12.3 Spacer size + 1.95 Cots Hardness + 5.0 BD*Spacer size
- 1.60 BD*Cots Hardness + 0.068 Spacer size*Cots Hardness



Inference: No significant factors are found, and no significant interactions are alsohappening among input variables







Inference: If lines are almost parallel to each other than the slopes are equals thus no interaction between the input variable. To some extent BD * Cots hardness has some interaction but not of statistical significance P value is 0.70

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Response Surface Regression: 10m Cv versus BD, Spacer size, Cots Hardness

Coded Coefficients

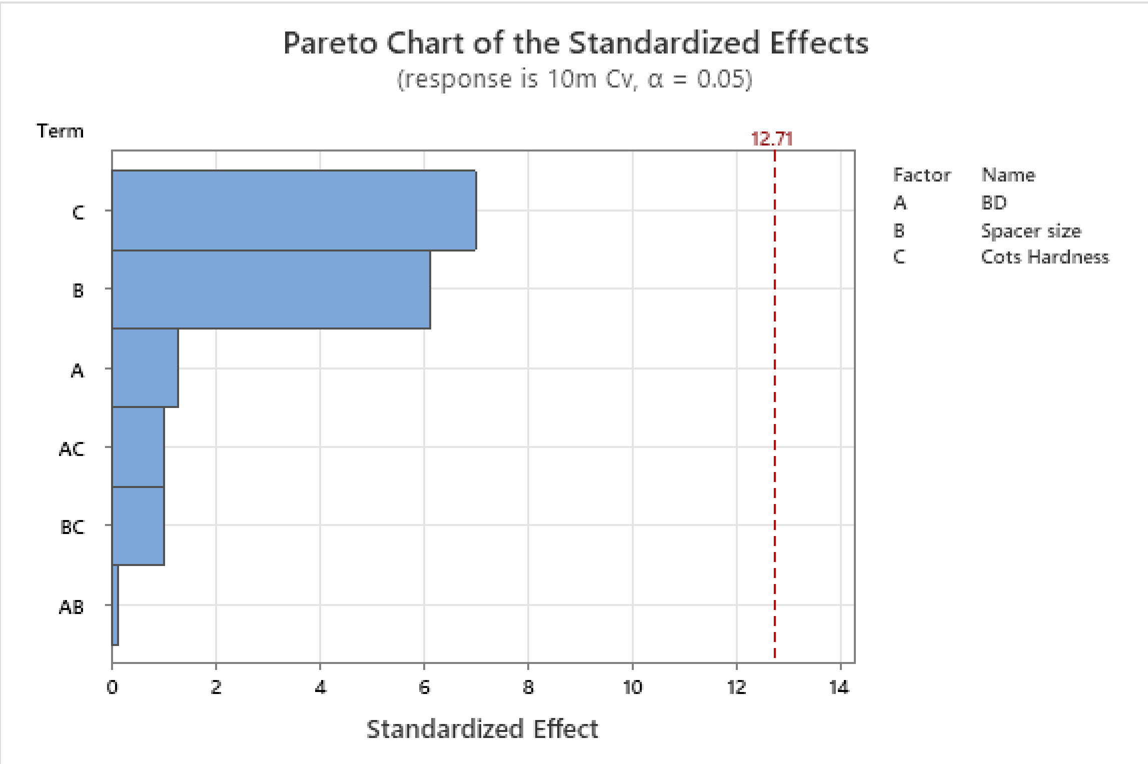
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.58375	0.00875	295.29	0.002	
BD	-0.01125	0.00875	-1.29	0.421	1.00
Spacer size	-0.05375	0.00875	-6.14	0.103	1.00
Cots Hardness	0.06125	0.00875	7.00	0.090	1.00
BD*Spacer size	0.00125	0.00875	0.14	0.910	1.00
BD*Cots Hardness	-0.00875	0.00875	-1.00	0.500	1.00
Spacer size*Cots Hardness	0.00875	0.00875	1.00	0.500	1.00

Model Summary

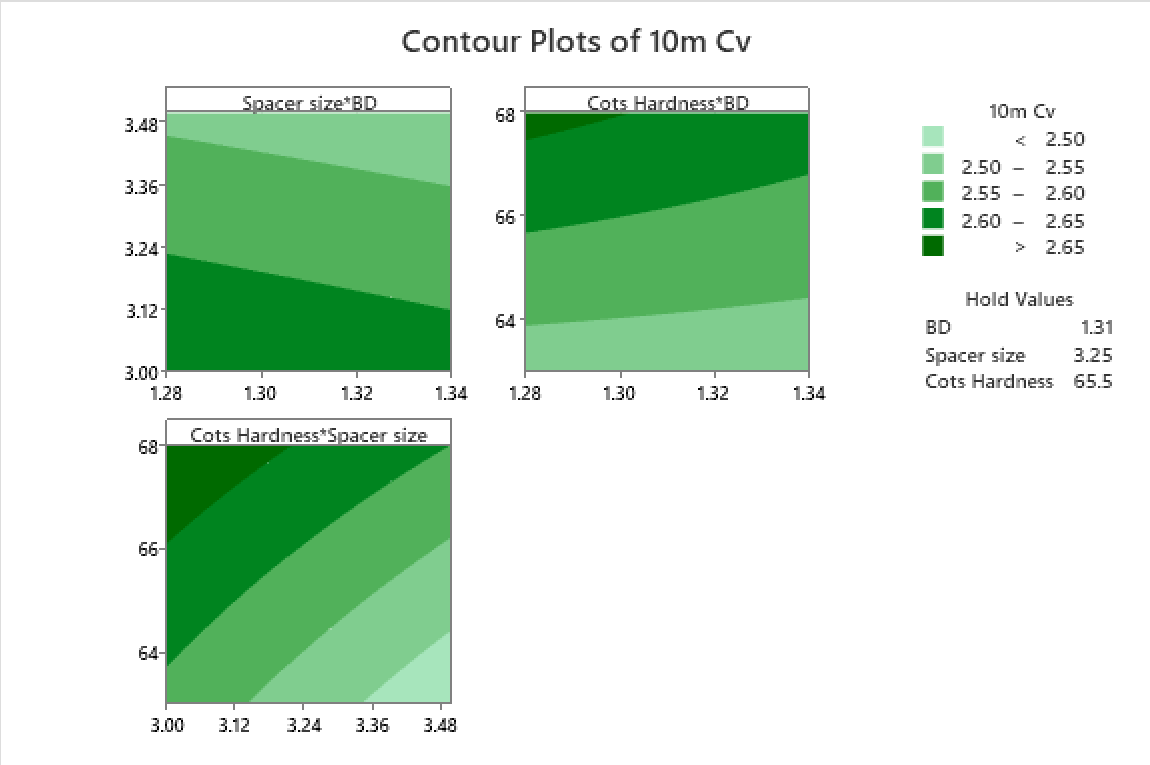
S	R-sq	R-sq(adj)	R-sq(pred)
0.0247487	98.91%	92.34%	29.98%

Regression Equation in Uncoded Units

10m Cv = -4.2 + 6.73 BD - 1.35 Spacer size + 0.132 Cots Hardness + 0.17 BD*Spacer size - 0.117 BD*Cots Hardness + 0.0140 Spacer size*Cots Hardness



Inference: No significant factors are found @ 5% alpha risk but @ 10% spacer size and cots hardness are significant, but no significant interactions are also happening among input variables


Contour Plots of 10m Cv
Spacer size*BD
Cots Hardness*BD
Cots Hardness*Spacer size
10m Cv
< 2.50
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2.55 – 2.60
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> 2.65
Hold Values
BD 1.31
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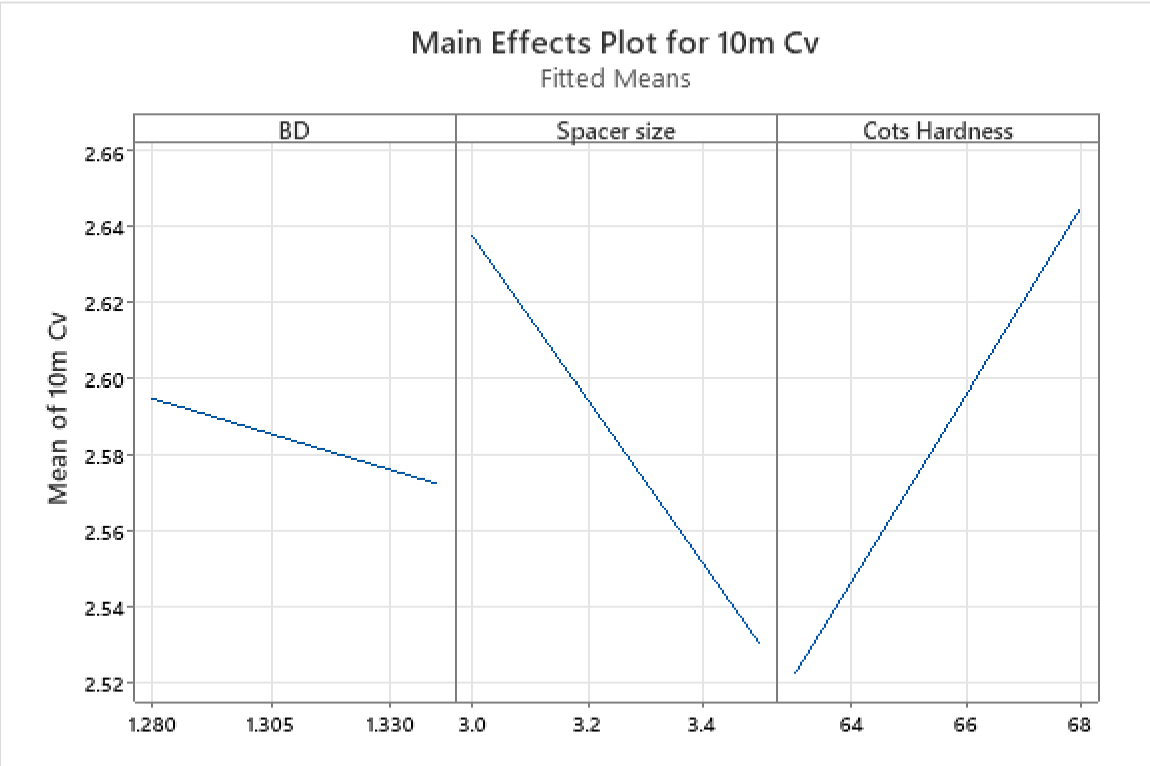
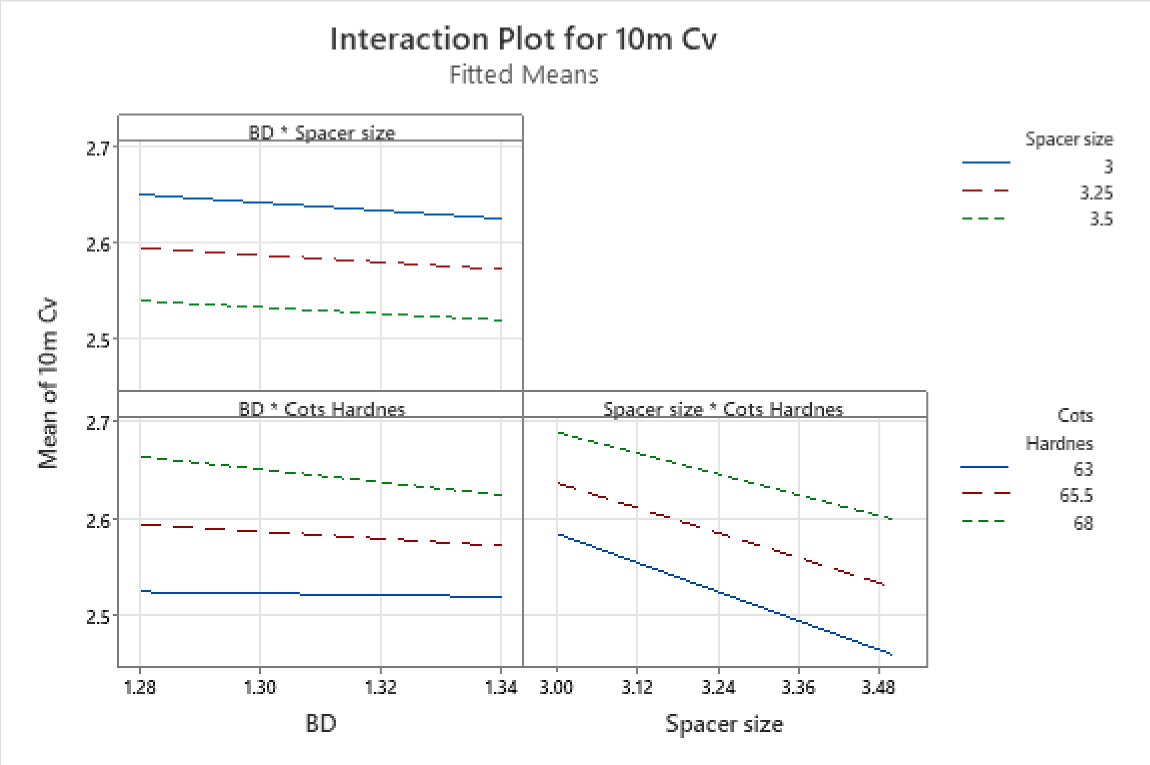

Main Effects Plot for 10m Cv
Fitted Means
BD
Spacer size
Cots Hardness
Mean of 10m Cv



Inference: If lines are almost parallel to each other than the slopes are equals thus nointeraction between the input variable.

Response Surface Regression: Hairiness H versus BD, Spacer size, Cots Hardness

Coded Coefficients

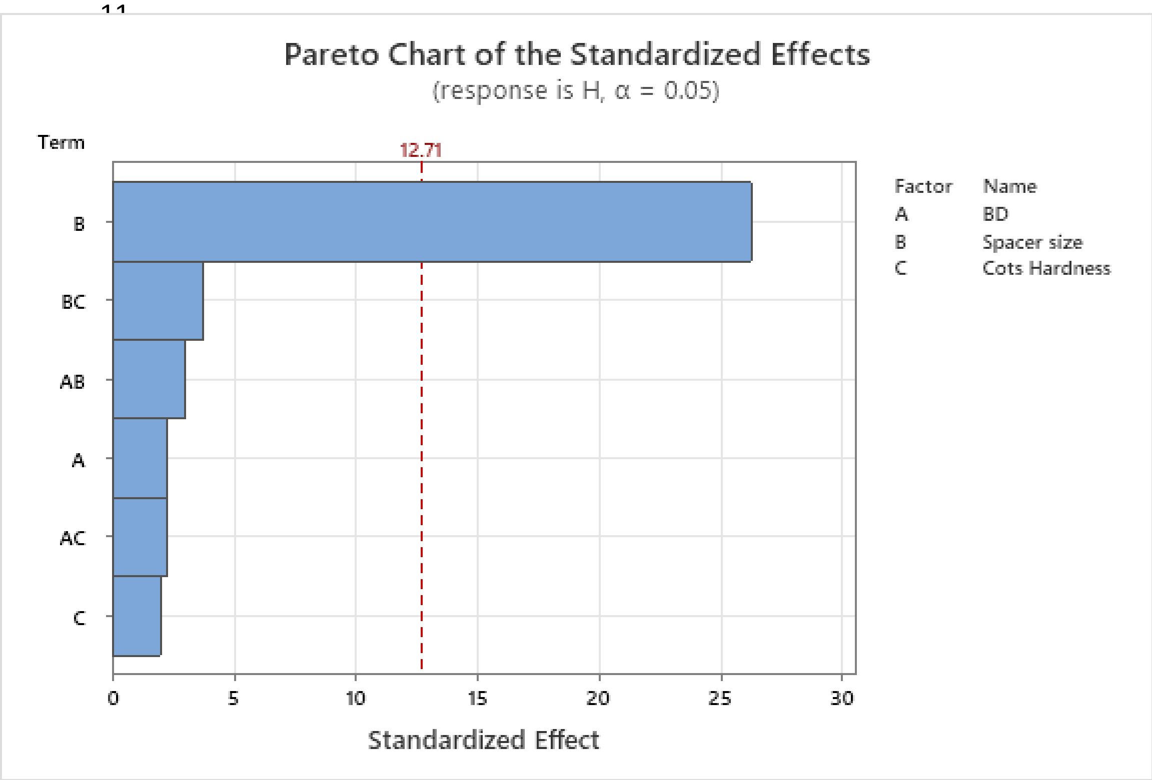
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	5.7850	0.0100	578.50	0.001	
BD	0.0225	0.0100	2.25	0.266	1.00
Spacer size	-0.2625	0.0100	-26.25	0.024	1.00
Cots Hardness	0.0200	0.0100	2.00	0.295	1.00
BD*Spacer size	-0.0300	0.0100	-3.00	0.205	1.00
BD*Cots Hardness	-0.0225	0.0100	-2.25	0.266	1.00
Spacer size*Cots Hardness	0.0375	0.0100	3.75	0.166	1.00

Model Summary

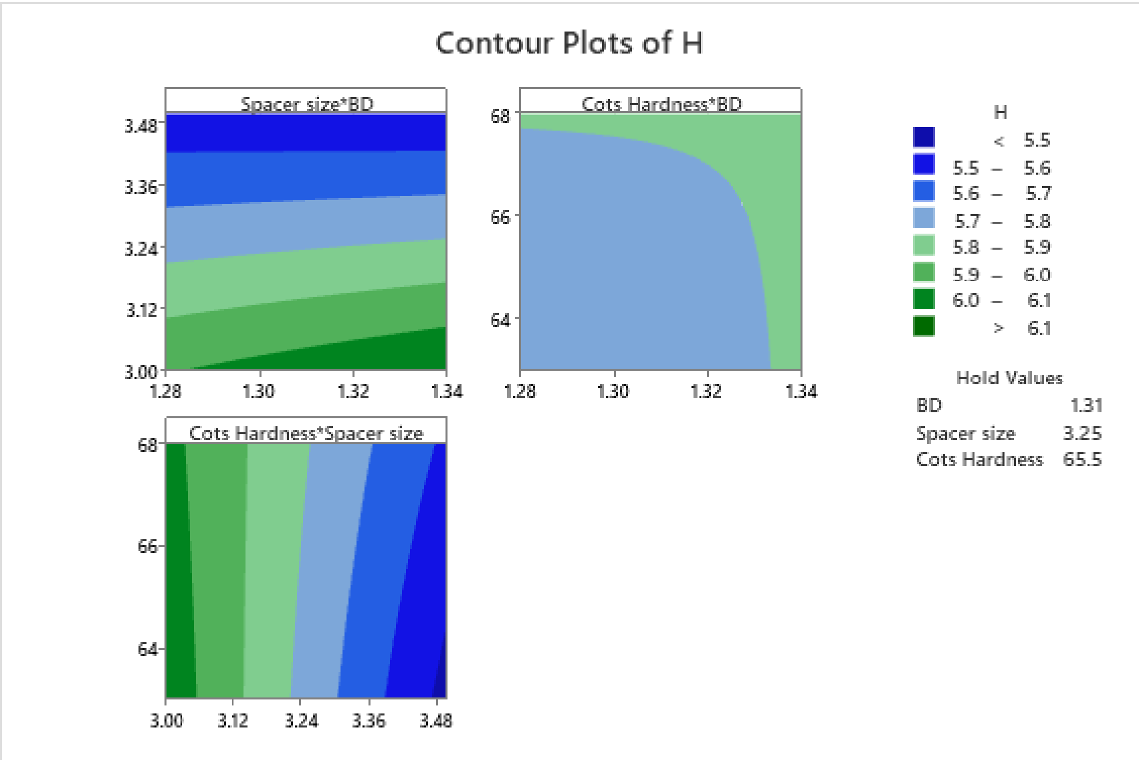
S	R-sq	R-sq(adj)	R-sq(pred)
0.0282843	99.86%	99.04%	91.20%

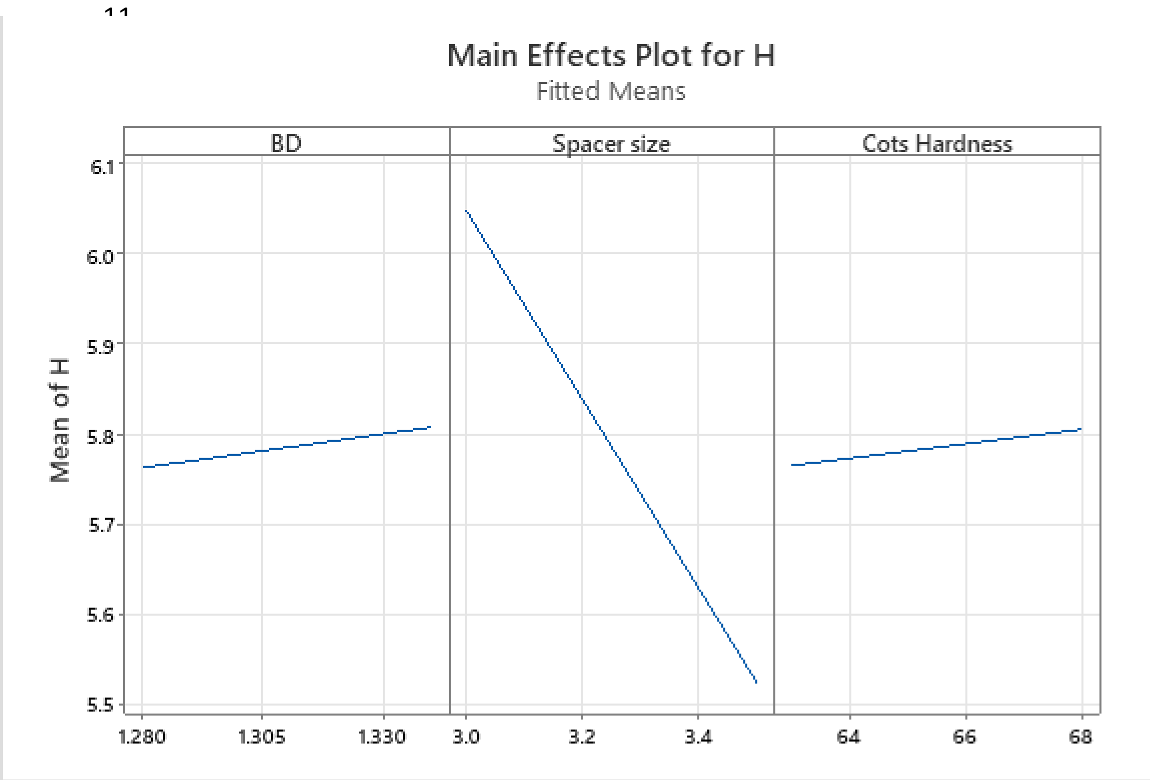
Regression Equation in Uncoded Units

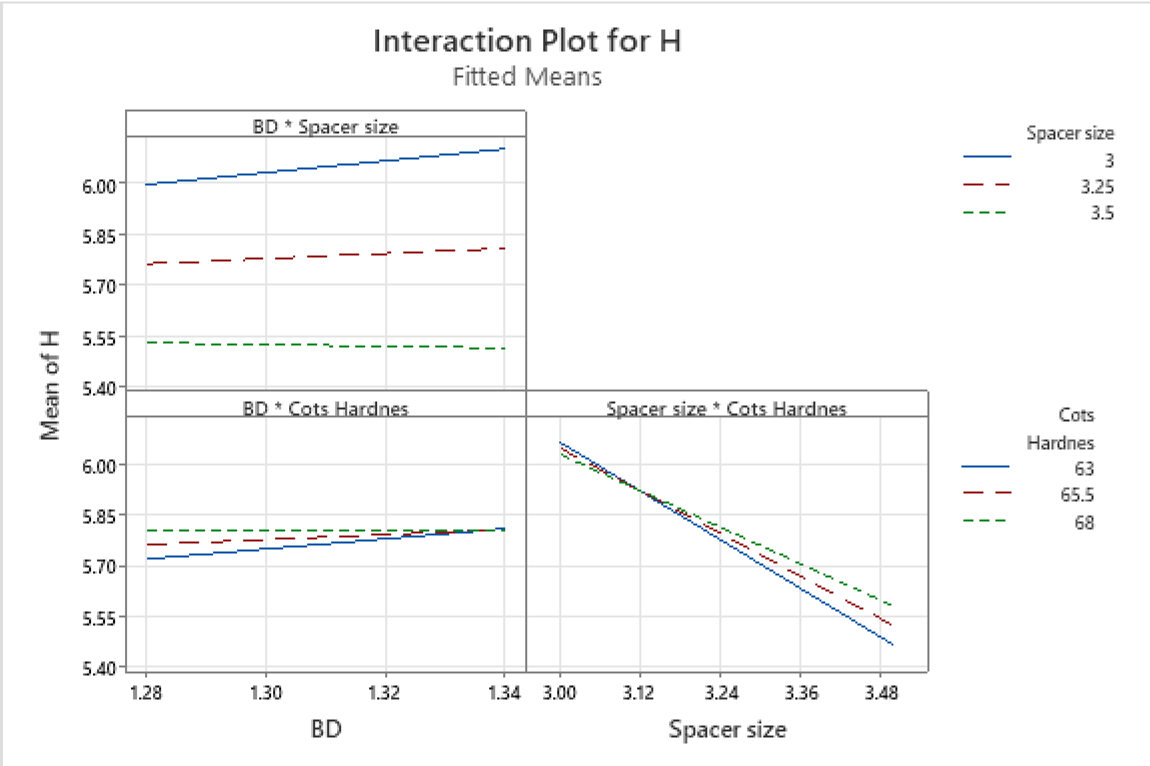
H = -22.3 + 33.40 BD + 0.26 Spacer size + 0.206 Cots Hardness - 4.00 BD*Spacer size - 0.300 BD*Cots Hardness + 0.0600 Spacer size*Cots Hardness



Inference: Spacer size seems to be very significant factors @ 5% alpha risk, but nosignificant interactions are also happening among input variables.







Inference: Spacer size and cots hardness are slightly interacting but it's not significanteven @ 10% alpha risk.

Response Surface Regression: IPI/km versus BD, Spacer size, Cots Hardness

Coded Coefficients

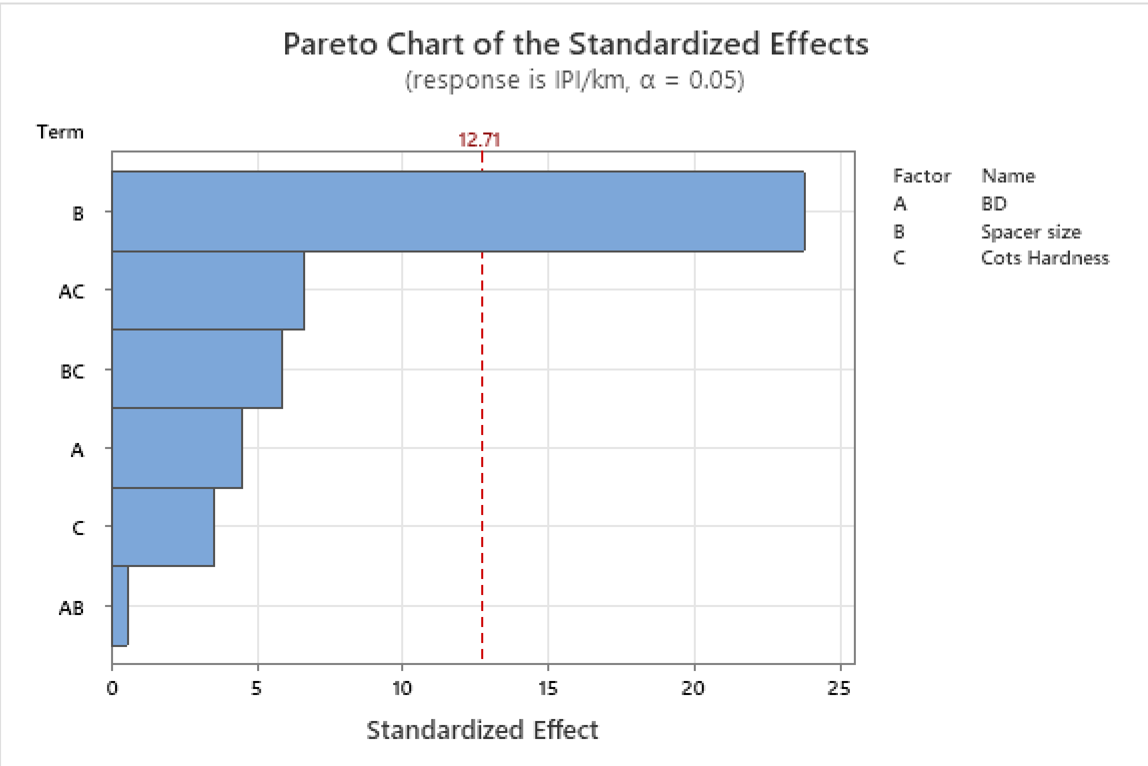
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	588.50	6.19	95.11	0.007	
BD	27.72	6.19	4.48	0.140	1.00
Spacer size	-147.02	6.19	-23.76	0.027	1.00
Cots Hardness	22.03	6.19	3.56	0.174	1.00
BD*Spacer size	-3.46	6.19	-0.56	0.675	1.00
BD*Cots Hardness	40.84	6.19	6.60	0.096	1.00
Spacer size*Cots Hardness	-36.38	6.19	-5.88	0.107	1.00

Model Summary

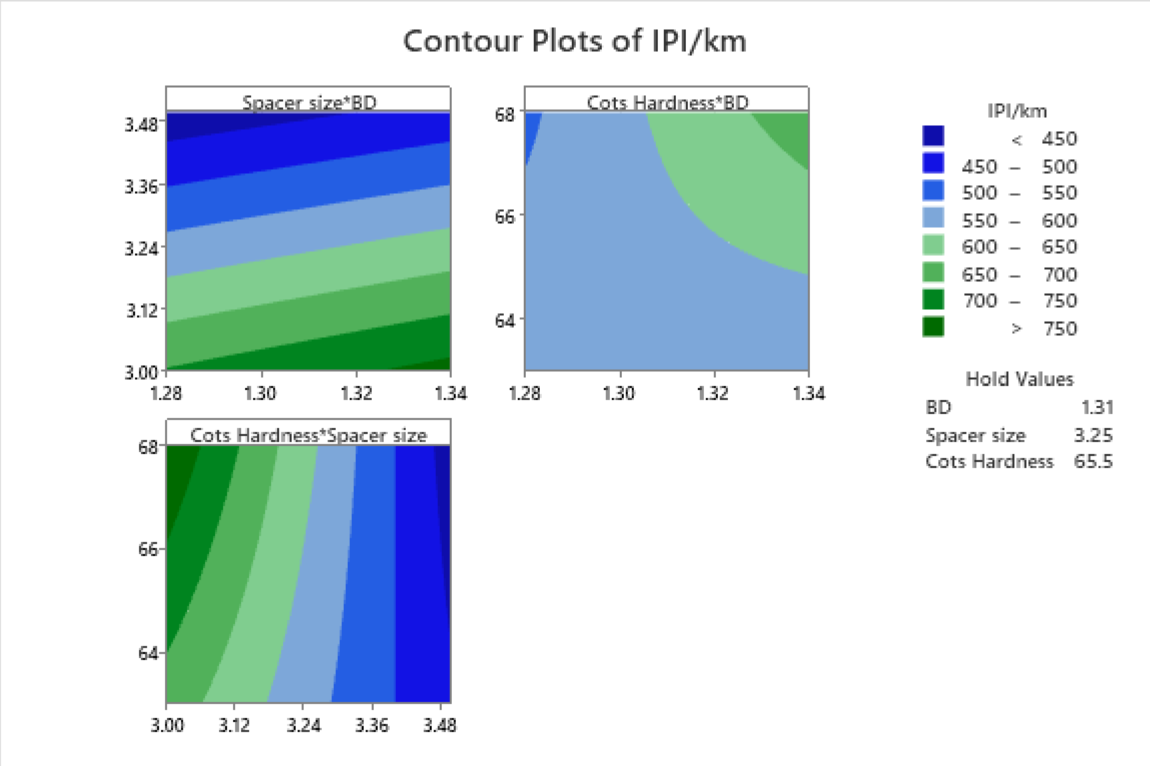
S	R-sq	R-sq(adj)	R-sq(pred)
17.5009	99.85%	98.97%	90.54%

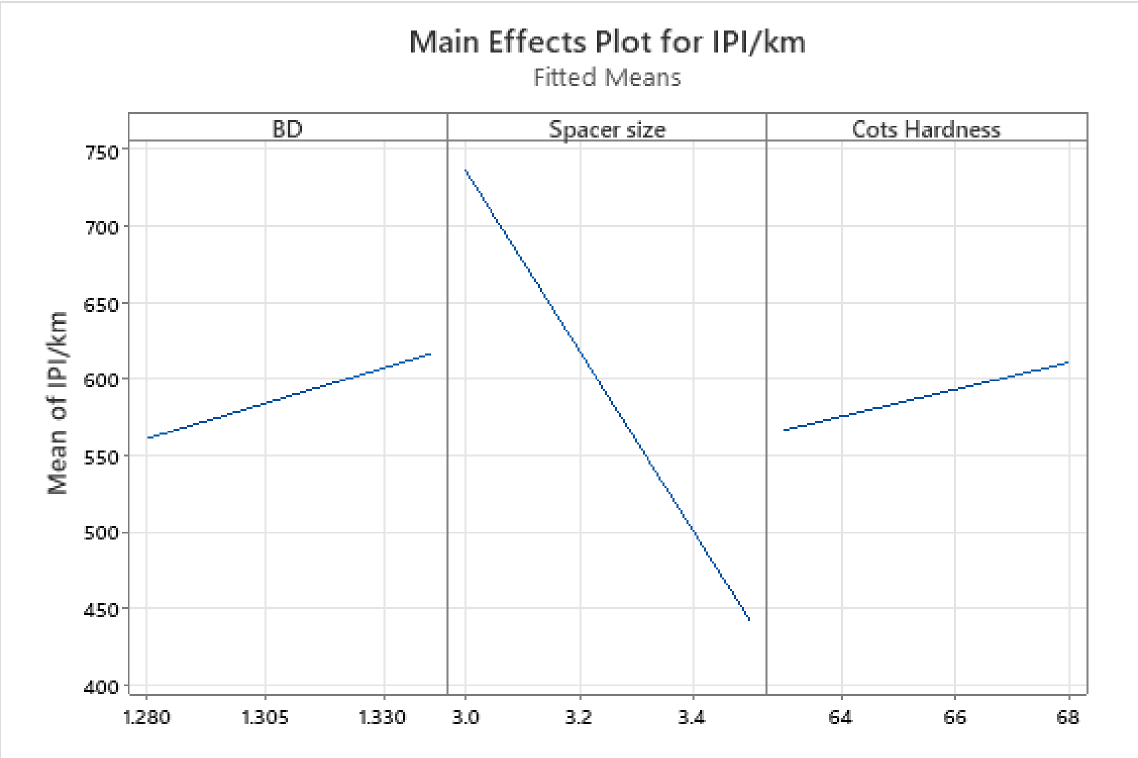
Regression Equation in Uncoded Units

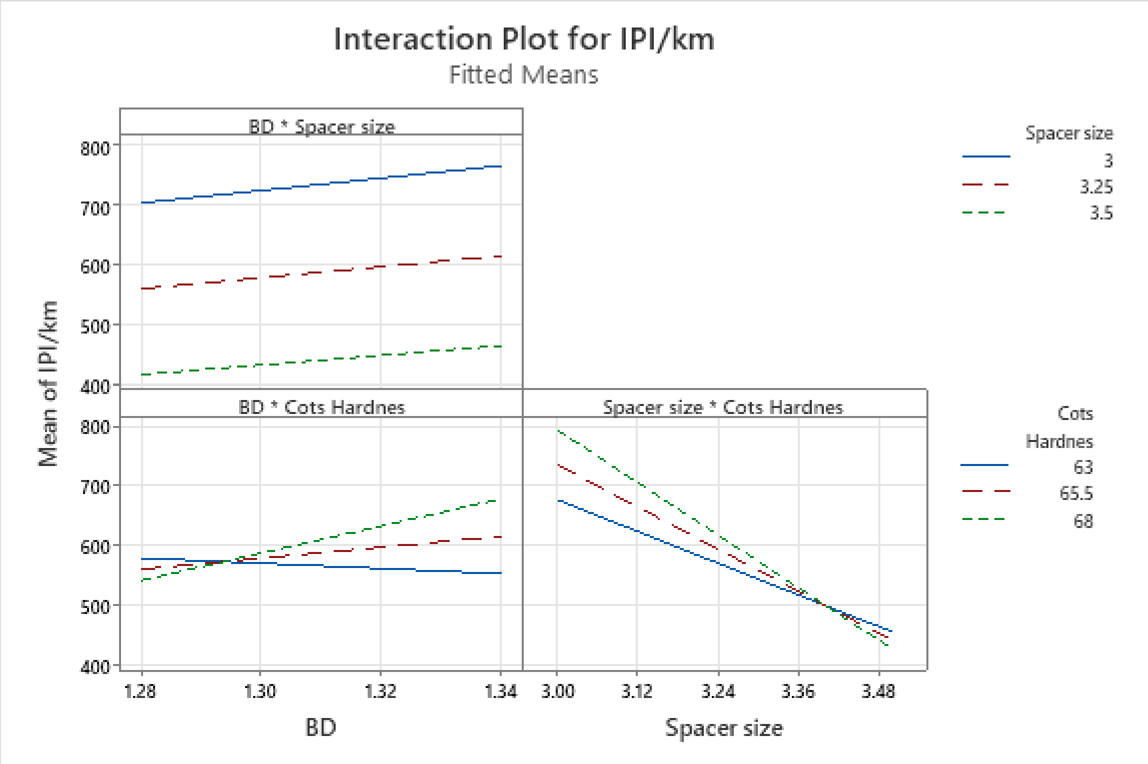
IPI/km = 33074 - 33239 BD + 3830 Spacer size - 515 Cots Hardness - 462 BD*Spacer size + 544.5 BD*Cots Hardness - 58.21 Spacer size*Cots Hardness



Inference: Spacer size seems to be very significant factors @ 5% alpha risk, @10% alpharisk BD and cots hardness, spacer size and cots hardness are having some interactions


Contour Plots of IPI/km
Spacer size*BD
Cots Hardness*BD
Cots Hardness*Spacer size
3.48
3.36
3.24
3.12
3.00
1.28
1.30
1.32
1.34
68
66
64
3.00
3.12
3.24
3.36
3.48
IPI/km
< 450
450 – 500
500 – 550
550 – 600
600 – 650
650 – 700
700 – 750
> 750
Hold Values
BD 1.31
Spacer size 3.25
Cots Hardness 65.5


Main Effects Plot for IPI/km
Fitted Means
BD
Spacer size
Cots Hardness
Mean of IPI/km
750
700
650
600
550
500
450
400
1.280
1.305
1.330
3.0
3.2
3.4
64
66
68



Inference: @10% alpha risk BD and cots hardness, spacer size and cots hardness are having some interactions

Response surface regression model Summary:

CSP	=	9331 - 11429 BD - 1669 Spacer size + 99.4 Cots Hardness + 3218 BD*Spacer size + 4.9 BD*Cots Hardness - 34.25 Spacer size*Cots Hardness
10m Cv	=	-4.2 + 6.73 BD - 1.35 Spacer size + 0.132 Cots Hardness + 0.17 BD*Spacer size - 0.117 BD*Cots Hardness + 0.0140 Spacer size*Cots Hardness
H	=	-22.3 + 33.40 BD + 0.26 Spacer size + 0.206 Cots Hardness - 4.00 BD*Spacer size - 0.300 BD*Cots Hardness + 0.0600 Spacer size*Cots Hardness
IPI/km	=	33074 - 33239 BD + 3830 Spacer size - 515 Cots Hardness - 462 BD*Spacer size + 544.5 BD*Cots Hardness - 58.21 Spacer size*Cots Hardness

Factor variable highlighted in red font is statistically significant and significant interaction is happening within the input variables also.

Predictive profiler:

The Predictive Profiler in JMP Pro allows users to visualize and understand the impact of different variables on a response or outcome variable in predictive models.

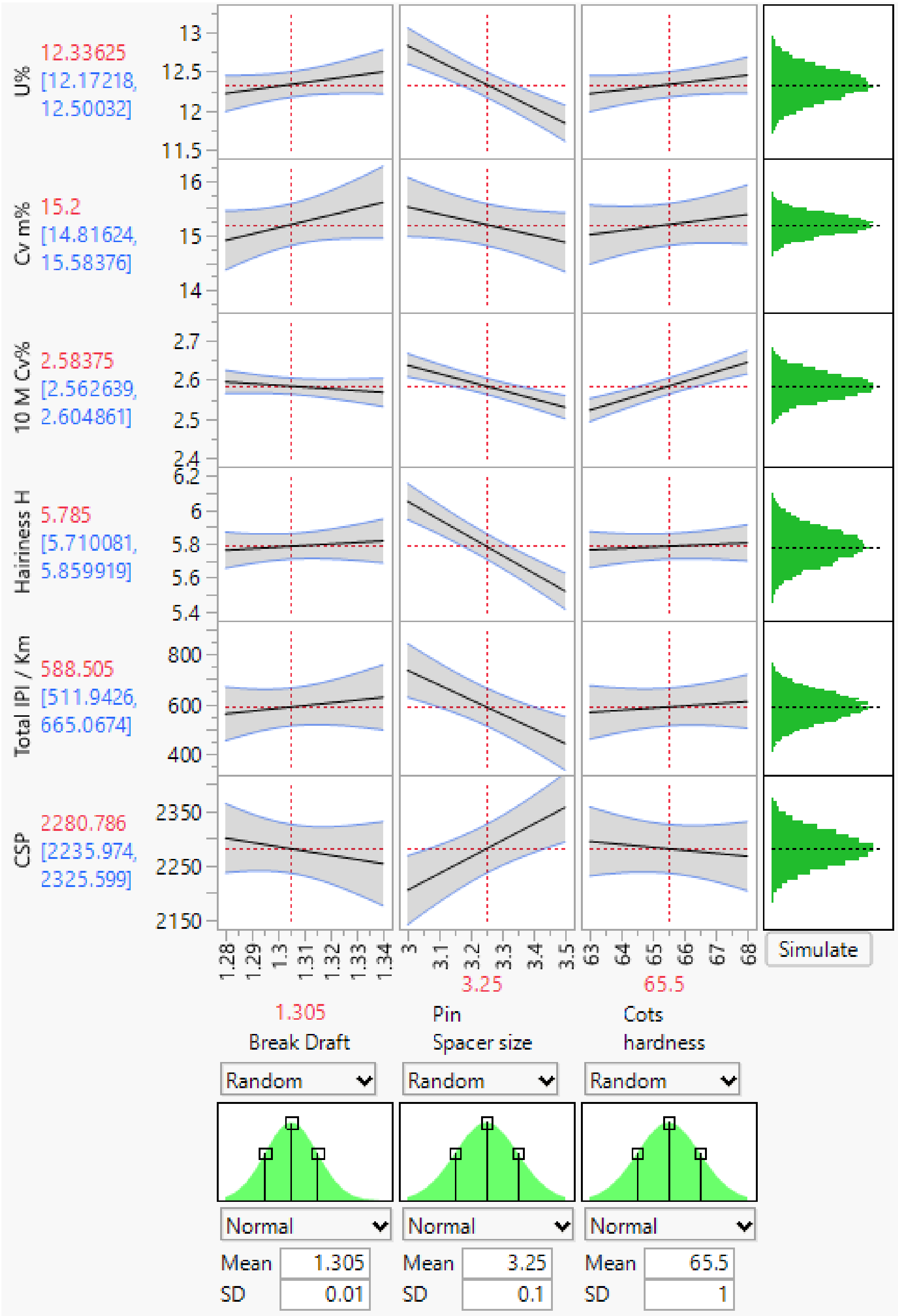
Explore Predictive Models: You can build various predictive models like regression, decision trees, neural networks, etc., and use the profiler to understand how changes in input variables affect the predicted outcomes.

Visualize Relationships: The profiler provides graphical representations (such as scatter plots, contour plots, etc.) to illustrate how changes in predictor variables influencethe response variable.

Optimize Models: Users can use the profiler to identify influential variables, detect interactions, and optimize model settings for better predictions.

Interactive Analysis: It allows for interactive exploration by dynamically adjusting variables and observing the corresponding changes in the predicted outcomes.

Model Validation: Evaluate the predictive accuracy of the model by comparing predicted values against actual values.



Conclusion:

The analysis of the relationship between drafting zone parameters and yarn quality attributes, particularly focusing on break draft, cots shore hardness, and pin spacer size, has yielded significant insights. By exploring response surface regression, factorial plots, and contour plots, the study discovered critical interactions among these factors influencing yarn properties. Pin spacer size emerged as a significant parameter impacting yarn quality, especially in enhancing evenness, imperfections, hairiness, and strength. Larger spacer sizes were found to improve yarn attributes by facilitating better fiber transfer and integration during drafting, resulting in a more structurally sound yarn.

The correlation study highlighted strong associations among yarn quality indicators like evenness (CVm), imperfections (10m CV), hairiness (H), and strength (CSP). These correlations underscored the complex interplay among these attributes, indicating their interdependence.

Moreover, the response surface regression analysis provided regression equations that accurately model the relationship between the studied factors and yarn quality attributes. The equations showcase how changes in break draft, pin spacer size, and cots shore hardness impact characteristics like unevenness, imperfections, hairiness, and tensile strength. While the Cronbach's Alpha based on standardized items showed improved internal consistency, indicating better reliability in the model, it's essential to note that certain response variables and input factors had different units of measurement. This variation could introduce some unexplained variance in the model.

Overall, the findings underscore the significance of optimizing drafting zone parametersin ring spinning to enhance yarn quality. The study's comprehensive analysis through response surface regression and correlation studies sheds light on the intricate relationships among these factors, offering valuable insights for the textile industry to improve yarn production processes.