

INEOS
Composites

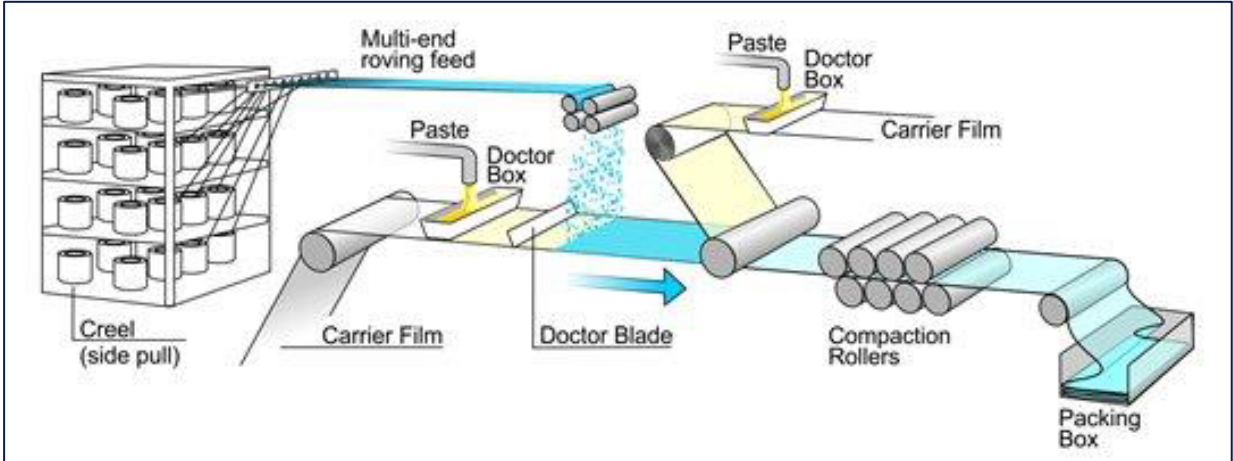
Man vs Machine

MaxDiff Study
Class A Surface Smoothness Evaluation

December 2023



SMC Process Overview



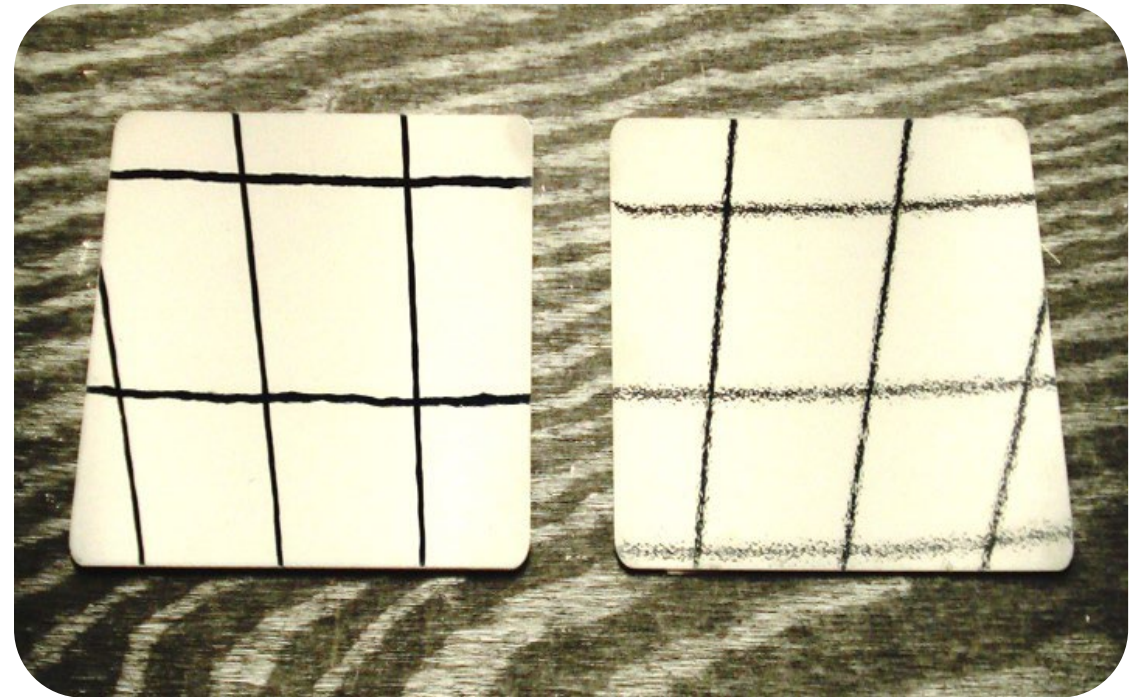
Class A Surface

Definitions

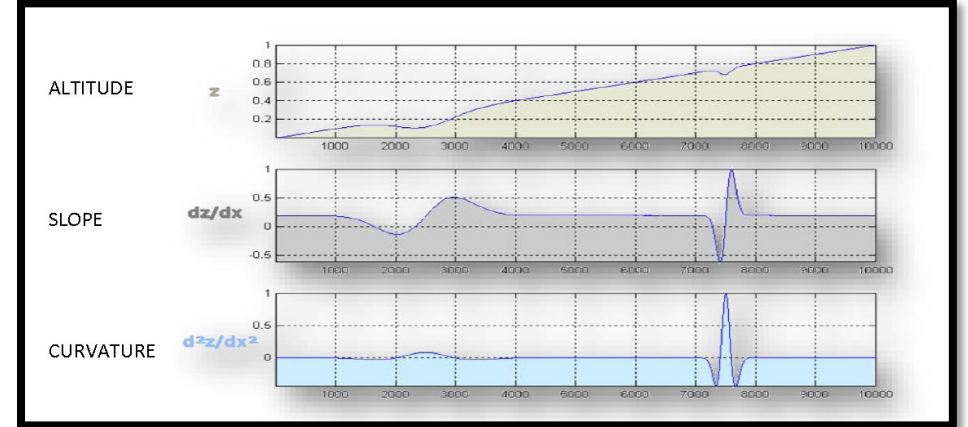
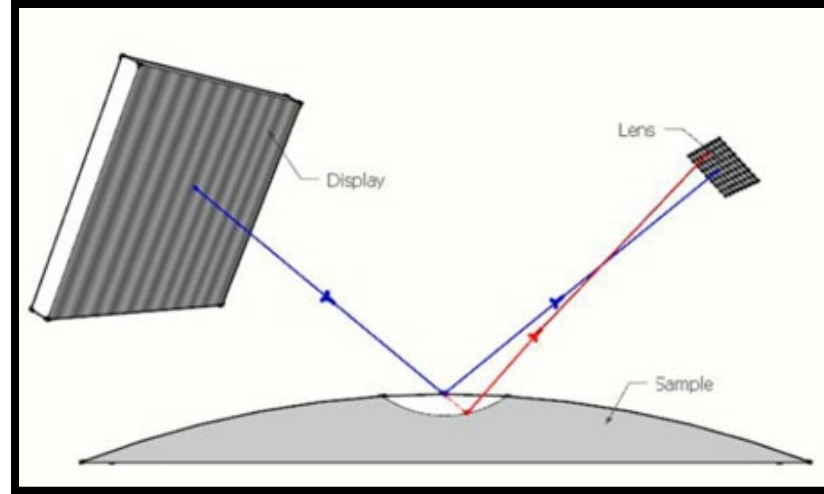
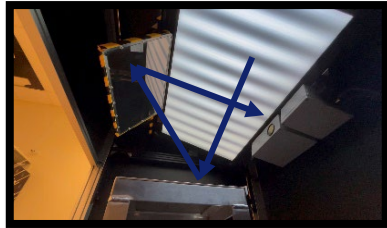
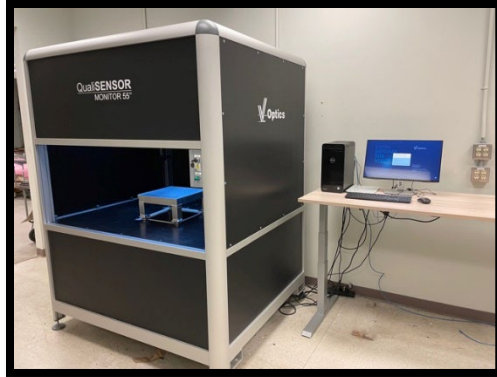
LONG TERM WAVINESS



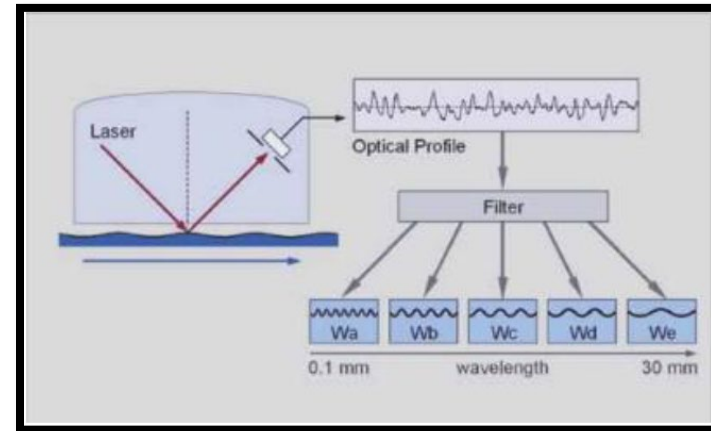
SHORT TERM WAVINESS (ORANGE PEEL)



Deflectometry



Wavelength	Feature	
A	Orange Peel	0.1-0.3 mm
B	Orange Peel	0.3-1.0 mm
C	Waviness	1.0-3.0 mm
D	Waviness	3.0-10.0 mm
E	Warp	10.0-30.0 mm



Based on Snell's Law
Curvature Maps for entire surface

- Vertical and Horizontal Curvature (1/m)
- avg
- max
- Min
- SD

Project Goals

- Purchase our product.
- Demonstrate our product can produce a Class A part.
- Remove subjectivity from evaluation.
 - Compare the deflectometer to visual evaluation (man vs machine).
 - Determine which outputs of the deflectometer correlate to visual evaluation.
- Drive industry acceptance of a new measurement tool.

MaxDiff Analysis

Obtaining Useful Data from Visual Inspection

How to remove subjectivity and generate a continuous output for data analysis.

MaxDiff (maximum difference scaling):

- Used in consumer research to compare prospective new products and determine consumer preferences
- Uses the framework of random utility theory. A choice is assumed to have an underlying value, or utility, to respondents.
- MaxDiff estimates these utilities and estimates the probabilities that a choice is preferred over another using logistic regression.

Marginal utility = indicator of the perceived value of a choice when compared to other choices

Marginal probability = estimated probability that someone will select that choice

MaxDiff Analysis - Example



MaxDiff Results			Flavor
Marginal Utility	Marginal Probability		
2.5862	0.2989		Oreo Cookie
2.2326	0.2099		Butter Pecan
1.8810	0.1477		Chocolate Chip
1.2881	0.0816		Chocolate
1.0168	0.0622		Coffee
0.8626	0.0533		Black Cherry
0.5397	0.0386		Mint Chocolate Chip
0.1542	0.0263		Fudge Swirl
-0.077	0.0208		Caramel Fudge Swirl
-0.390	0.0152		Vanilla
-0.456	0.0143		Strawberry
-0.892	0.0092		Orange Strawberry
-1.140	0.0072		Peanutbutter Chocolate
-1.508	0.0050		Walnut
-1.552	0.0048		Lime
-1.932	0.0033		Pistachio
-2.615	0.0016		Birthday Cake

Creating the Design

1. Start with a jmp table containing the “options”.
2. DOE > Consumer Studies > MaxDiff Design
 1. Select your table.
 2. Cast column to X,Factor
 3. Enter # profiles per choice set (number of choices) = 3
 4. Enter # of choice sets = 12
3. Make Design
4. Make Table

Flat Panel Visual MaxDiff

- 8 Panels
- 18 Judges
 - 3 Different Companies – various levels of SMC experience
- 12 Choice Sets

- Provide the survey to the respondents
- Record the data in the table.
- Copy the full choice set for each respondent.

Flat Panel Survey Results - JMP

File Edit Tables Rows Cols DOE Analyze Graph Tools Add-Ins View Window Help

Flat Panel Survey Results

Source

	Choice Set	Panel(Effect)	Subject	Rank	Con
1	1 B		1	3	B
2	1 D		1	1	B
3	1 G		1	2	B
4	2 F		1	2	B
5	2 A		1	1	B
6	2 B		1	3	B
7	3 A		1	2	B
8	3 D		1	3	B
9	3 E		1	1	B
10	4 F		1	1	B
11	4 G		1	2	B
12	4 C		1	3	B
13	5 E		1	2	B
14	5 H		1	1	B
15	5 C		1	3	B
16	6 D		1	2	B
17	6 H		1	1	B
18	6 F		1	3	B
19	7 G		1	3	B
20	7 H		1	1	B
21	7 A		1	2	B
22	8 F		1	3	B
23	8 E		1	2	B
24	8 A		1	1	B
25	9 E		1	1	B
26	9 B		1	2	B
27	9 G		1	3	B
28	10 H		1	1	B
29	10 C		1	3	B
30	10 B		1	2	B
31	11 C		1	3	B
32	11 D		1	2	B
33	11 A		1	1	B
34	12 B		1	2	B
35	12 C		1	3	B
36	12 D		1	1	B
37	1 B		2	2	B
38	1 D		2	1	B
39	1 G		2	3	B
40	2 F		2	2	B
41	2 A		2	1	B
42	2 B		2	3	B
43	3 A		2	2	B
44	3 D		2	3	B

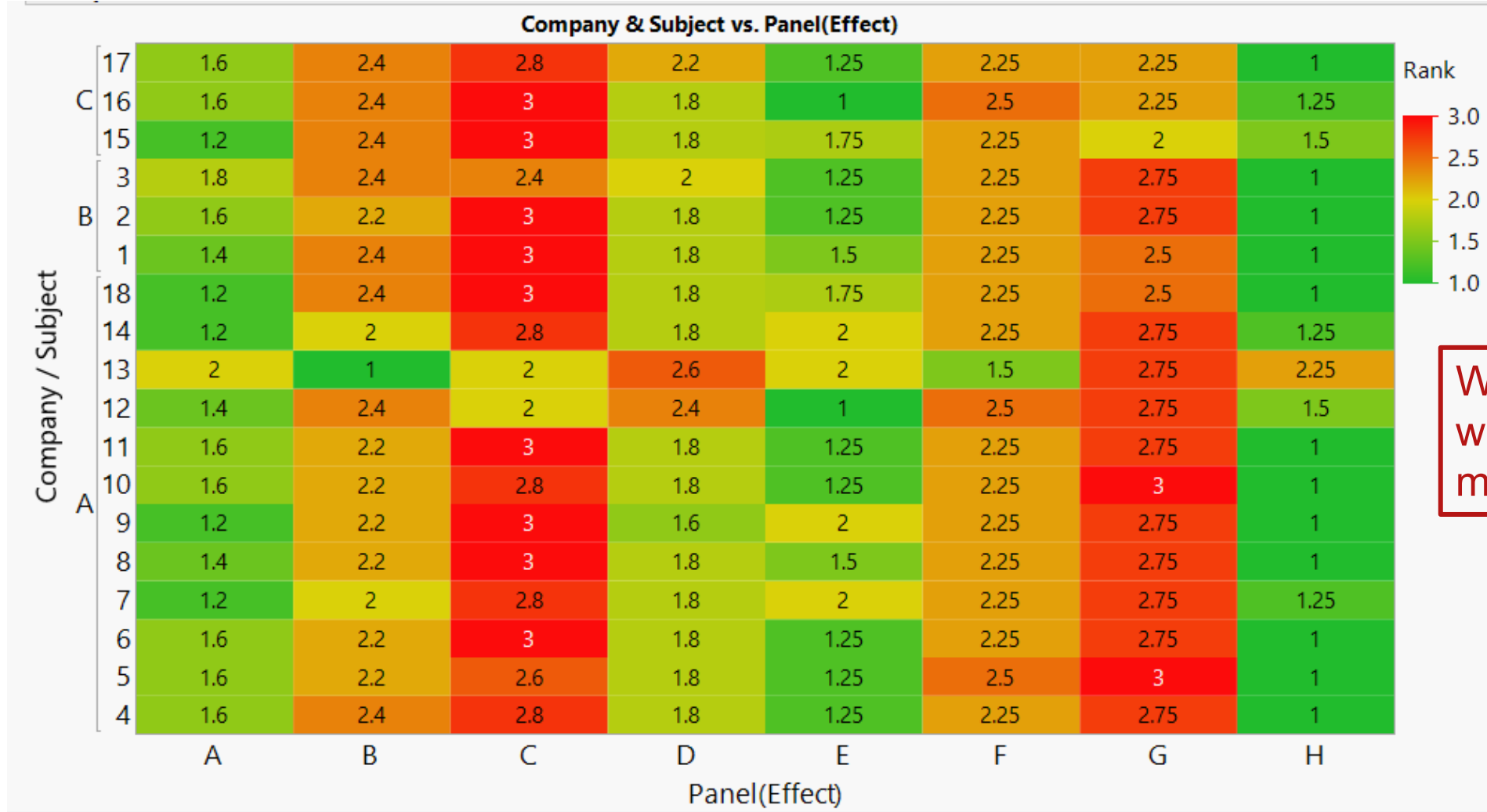
Columns (5/0)

Choice Set
Panel(Effect)
Subject
Rank
Company

Rows

All rows	648
Selected	0
Excluded	0
Hidden	0
Labeled	0

Heatmap



What if Judge 13 was the decision maker?

MaxDiff Analysis

1. Analyze > Consumer Research > MaxDiff
2. DOE > Consumer Studies > MaxDiff Design
 1. Response Indicator
 2. Subject ID
 3. Choice Set ID
 4. Construct Profile Effects
3. Make Design
4. Make Table
5. Save Utility Formula

MaxDiff Results

Panel

MaxDiff Model

MaxDiff Results

Marginal Utility	Marginal Probability		Panel(Effect)
2.3610	0.4946		H
1.5185	0.2130		E
1.3626	0.1822		A
0.0565	0.0494		D
-0.478	0.0289		F
-0.929	0.0184		B
-1.804	0.0077		G
-2.087	0.0058		C

MaxDiff Results (by Company)

Panel

MaxDiff Model - JMP

Data Format: One Table, Stacked

Select Data Table: Flat Panel Survey Results

Select Columns: 5 Columns (Choice Set, Panel(Effect), Subject, Rank, Company)

Pick Role Variables:

- Response Indicator: Rank
- Subject ID: Subject
- Choice Set ID: Choice Set
- Grouping: optional
- By: Company

Buttons: Run Model, Help, Remove

Options: Firth Bias-Adjusted Estimates

Construct Profile Effects: Panel(Effect)

Construct Subject Effects (Optional):

Best: 1, Worst: 3

MaxDiff Model Company=A

MaxDiff Results

Marginal Utility	Marginal Probability		Panel(Effect)
2.1322	0.4560		H
1.3375	0.2060		A
1.2784	0.1942		E
0.1370	0.0620		D
-0.346	0.0383		F
-0.665	0.0278		B
-1.814	0.0088		C
-2.061	0.0069		G

MaxDiff Model Company=C

MaxDiff Results

Marginal Utility	Marginal Probability		Panel(Effect)
1.8769	0.3328		E
1.8486	0.3235		H
1.4561	0.2185		A
-0.045	0.0487		D
-0.547	0.0295		G
-0.561	0.0291		F
-1.240	0.0147		B
-2.788	0.0031		C

Parameter Estimates

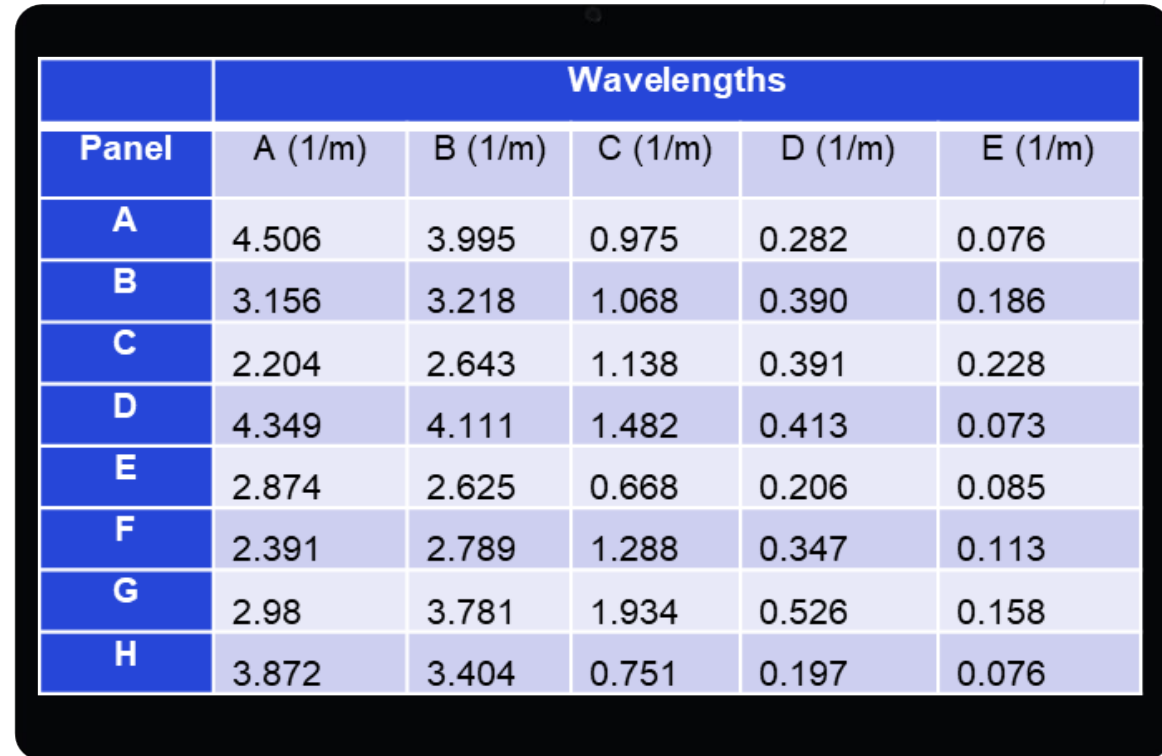
MaxDiff Model Company=B

MaxDiff Results

Marginal Utility	Marginal Probability		Panel(Effect)
4.5822	0.8516		H
2.4787	0.1039		E
1.2946	0.0318		A
-0.244	0.0068		D
-0.979	0.0033		F
-1.847	0.0014		B
-2.504	0.0007		G
-2.782	0.0005		C

Deflectometer Results

All panels were measured with the deflectometer.



	Wavelengths				
Panel	A (1/m)	B (1/m)	C (1/m)	D (1/m)	E (1/m)
A	4.506	3.995	0.975	0.282	0.076
B	3.156	3.218	1.068	0.390	0.186
C	2.204	2.643	1.138	0.391	0.228
D	4.349	4.111	1.482	0.413	0.073
E	2.874	2.625	0.668	0.206	0.085
F	2.391	2.789	1.288	0.347	0.113
G	2.98	3.781	1.934	0.526	0.158
H	3.872	3.404	0.751	0.197	0.076

Model Fit: Utility Factor vs Deflectometer Data

The screenshot shows the JMP software interface. A data table is visible in the background with columns labeled A, B, C, D, and E. The data values are as follows:

	A	B	C	D	E
749	0.2818	0.0758			
668	0.3092	0.1805			
138	0.3909	0.2279			
482	0.413	0.0726			
661	0.2056	0.085			
288	0.347	0.1157			
934	0.5261	0.1579			
513	0.1967	0.0755			

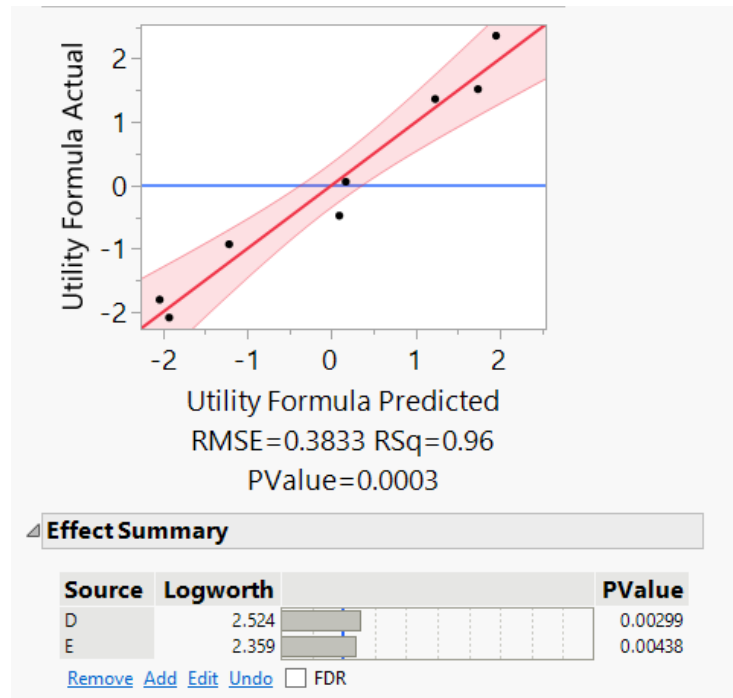
The 'Fit Model - JMP' dialog box is open, showing the following configuration:

- Model Specification:**
 - Select Columns: 11 Columns (Choice Set, Panel(Eff), Subject, Rank, Company, Utility Formula, A, B, C, D, E)
 - Pick Role Variables: Y = Utility Formula (optional)
 - Weight: optional numeric
 - Freq: optional numeric
 - By: optional
 - Personality: Standard Least Squares
 - Emphasis: Effect Screening
 - Buttons: Help, Run, Recall, Remove
 - Keep dialog open:
- Construct Model Effects:**
 - Add: A, B, C, D, E
 - Cross: A, B, C, D, E
 - Nest: A, B, C, D, E
 - Macros: [Dropdown]
 - Degree: 2
 - Attributes: [Dropdown]
 - Transform: [Dropdown]
 - No Intercept:

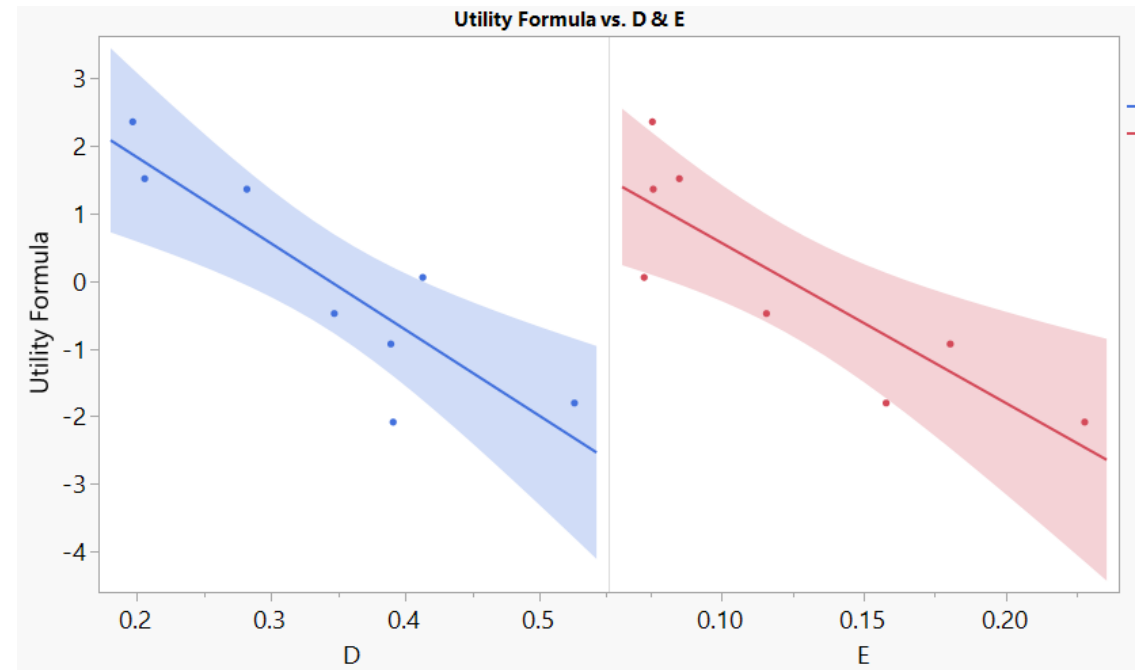
Reduced Model

Results

MODEL FIT



MAIN EFFECTS PLOTS



Deflectometer and JMP

- MSA on the deflectometer
- Regression analysis of ALSA output to Deflectometer output
 - Equation to estimate ALSA
- Numerous DOEs to understand effects of changes to product formulations on deflectometer output (surface smoothness)



Summary & Conclusions

- MaxDiff is an effective tool to obtain rankings of qualitative data (appearance, odor, taste, etc.)
- Use output of MaxDiff for further data analysis.
- Project demonstrated that the deflectometer is an appropriate tool to measure surface smoothness.
 - Industry acceptance
 - Quicker development time. Formulation and processing DOEs vs deflectometer output. (No longer have to wait for subjective visual evaluation.)