Discovery Summit Americas 2023

Utilizing JMP Data Analytics for Product Development of Adhesives and Sealants

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Henkel Corporation
Oct. 18. 2023

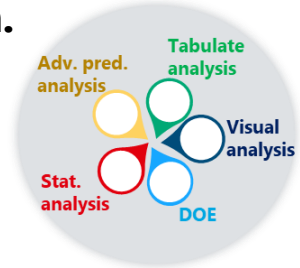
Henkel

AGENDA

- **Introduction**
- **About Henkel**
- **Application gallery :**
  - Cases utilizing JMP in product development at various stages
- **JMP-based formulation worksheets**
  - Introduction
  - Demonstration
- **Summary**

IMPRESSION - TO SOME FOLKS WITHIN HENKEL
"JMP IS AN ADVANCED DOE SOFTWARE"

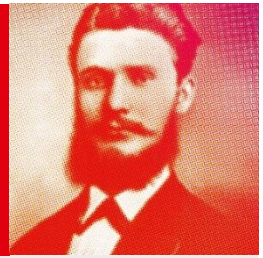
- **True!**
  - **But it is not the whole truth.**
    - **Limited adoption**
    - **Other software options**
- **How to promote adoption?**
  - **Emphasize data analytics**
  - **Need examples**
    - **Related to adhesive/sealant**
    - **Speak Our Language!**



ABOUT HENKEL …

SALES

€22.4 BN



€2.3 BN

ADJUSTED OPERATING PROFIT (EBIT)

146 YEARS

SUCCESS WITH BRANDS AND TECHNOLOGIES

WE EMPLOY MORE THAN

52,000

PEOPLE WORLDWIDE FROM 124 NATIONALITIES

[1] Figure relates to the 2022 fiscal year compared to the 2010 base year

Henkel adhesive technologies

GLOBAL ADHESIVE LEADER

SERVING

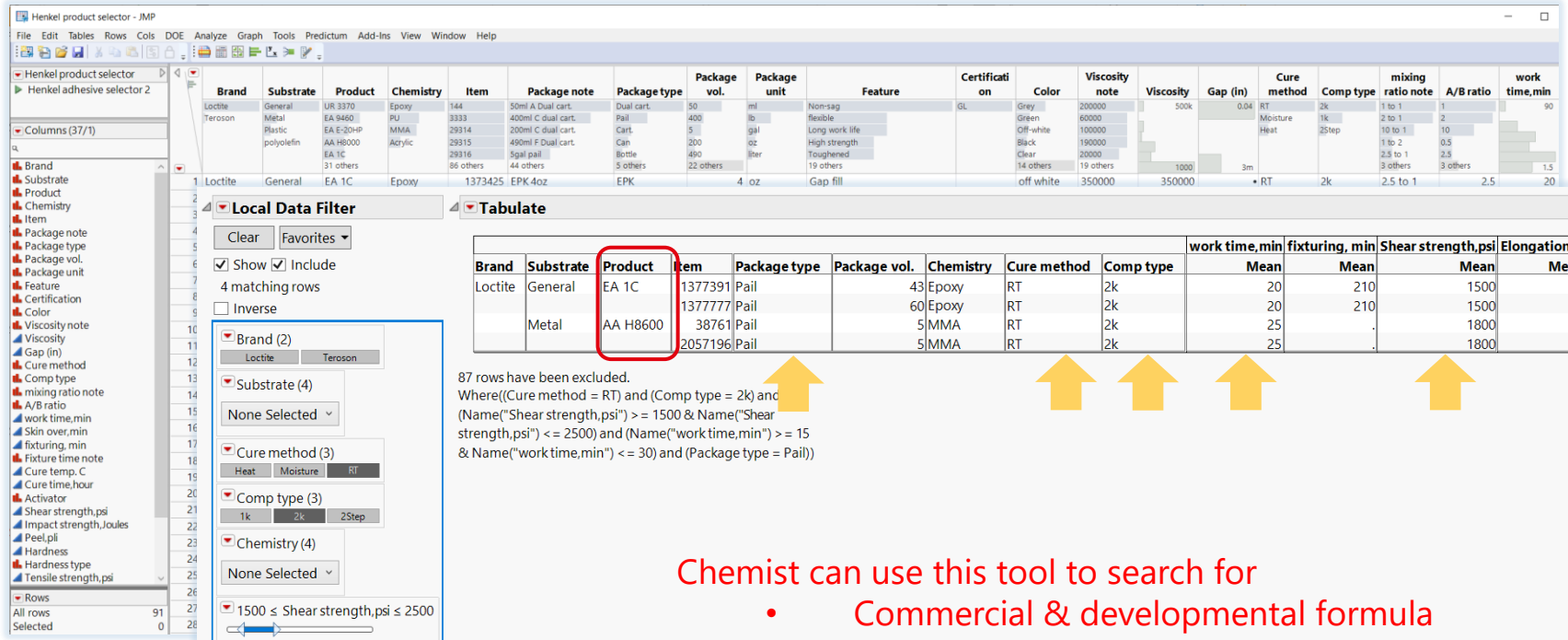
- **130,000** direct customers
- **75** countries
- **>800** industries

SUPPORTED BY

- **6,500** customer experts
- **100** manufacturing sites
- **20,000** products

PRE-FORMULATION STAGE

CASE 1: PRODUCTION SELECTOR GUIDE



Brand	Substrate	Product	Item	Package type	Package vol.	Chemistry	Cure method	Comp type	work time,min Mean	fixturing, min Mean	Shear strength,psi Mean	Elongation,% Mean	upper Temp. resist,F Mean
Loctite	General	EA 1C	1377391	Pail	43	Epoxy	RT	2k	20	210	1500	.	250
			1377777	Pail	60	Epoxy	RT	2k	20	210	1500	.	250
	Metal	AA H8600	38761	Pail	5	MMA	RT	2k	25	.	1800	.	.
			2057196	Pail	5	MMA	RT	2k	25	.	1800	.	.

Chemist can use this tool to search for

- Commercial & developmental formula
- Patent & literature
- Raw materials
- …

PRE-FORMULATION STAGE

CASE 2: RAW MATERIAL: SILVER MULTIVARIABLE ANALYSIS

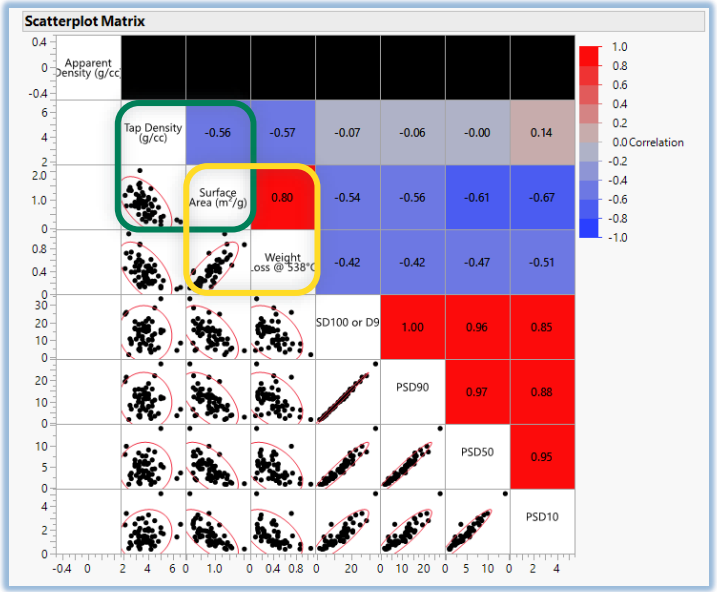
Silver_LA - JMP Pro

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

Silver_LA
- Multivariate
- Selector AB2
- Tabulat...n house
- Tap De... 3 more
- PCA flake
- Princip...relations
- Multiva...e - 2/26
- Tabulat...Ag 2/26
- Multiva...e - 7/11

Columns (22/0)
- Appar... (g/cc)
- Tap D...y (g/cc)
- Surfac... (m²/g)
- Weigh... 538°C

	Supplier 2	Category	Ag Name	Apparent Density (g/...	Tap Density (g/cc)	Surface Area (m²/g)	Weight Loss @ 538°C	PSD100 or D95
1	Supplier 2	Ag Flake	Ag_1	1.79	3.45	0.72	0.37	21.98
2	Supplier 2	Ag Flake	Ag_2	1.53	3.00	1.02	0.49	26.83
3	Supplier 2	Ag Flake	Ag_3	1.81	3.57	0.96	0.38	39.55
4	Supplier 2	Ag Flake	Ag_4	1.96	3.65	0.79	0.32	38.80
5	Supplier 2	Ag Flake	Ag_5	1.35	2.21	1.00	0.75	47.03
6	Supplier 2	Ag Flake	Ag_6	3.47	4.91	0.25	0.12	36.87
7	Supplier 2	Ag Flake	Ag_7	2.00	3.40	0.53	0.32	41.96
8	Supplier 2	Ag Flake	Ag_8	1.91	3.74	0.92	0.37	23.69
9	Supplier 2	Ag Flake	Ag_9	2.26	4.18	0.30	0.28	30.16
10	Supplier 2	Ag Flake	Ag_10	1.95	3.50	0.54	0.22	54.38
11	Supplier 2	Ag Flake	Ag_11	1.89	2.76	0.68	0.30	62.40



Analyze>Multivariate methods>multivariate

Multivariate

Correlations

	Apparent Density (g/cc)	Tap Density (g/cc)	Surface Area (m²/g)	Weight Loss @ 538°C	PSD100 or D95	PSD90	PSD50	PSD10
Apparent Density (g/cc)	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Tap Density (g/cc)	0.0000	1.0000	-0.5648	-0.5688	-0.0668	-0.0637	-0.0021	0.1399
Surface Area (m²/g)	0.0000	-0.5648	1.0000	0.8044	-0.5417	-0.5550	-0.6118	-0.6672
Weight Loss @ 538°C	0.0000	-0.5688	0.8044	1.0000	-0.4196	-0.4213	-0.4696	-0.5052
PSD100 or D95	0.0000	-0.0668	-0.5417	-0.4196	1.0000	0.9973	0.9553	0.8522
PSD90	0.0000	-0.0637	-0.5550	-0.4213	0.9973	1.0000	0.9722	0.8774
PSD50	0.0000	-0.0021	-0.6118	-0.4696	0.9553	0.9722	1.0000	0.9519
PSD10	0.0000	0.1399	-0.6672	-0.5052	0.8522	0.8774	0.9519	1.0000

There are 57 missing values. The correlations are estimated by Pairwise method.

PRE-FORMULATION STAGE

CASE 3: EPOXY LITERATURE LEARNING VIA DOE MODELING

RSC Advances

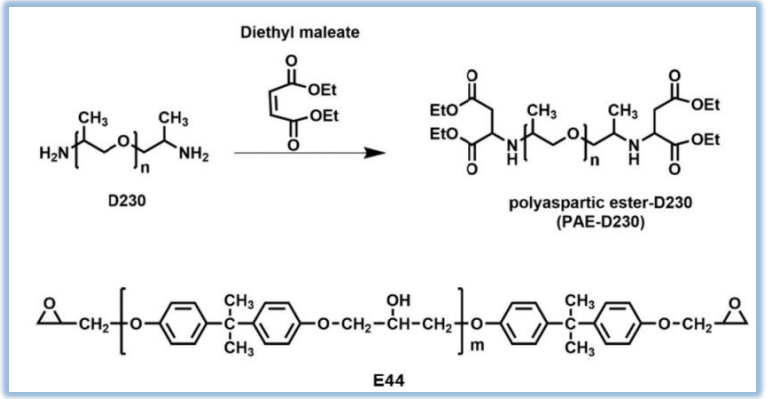
PAPER

View Article Online

Check for updates

Facile preparation of epoxy based elastomers with tunable T_gs and mechanical properties

https://pubs.rsc.org/en/content/articlelanding/2018/ra/c8ra00894a



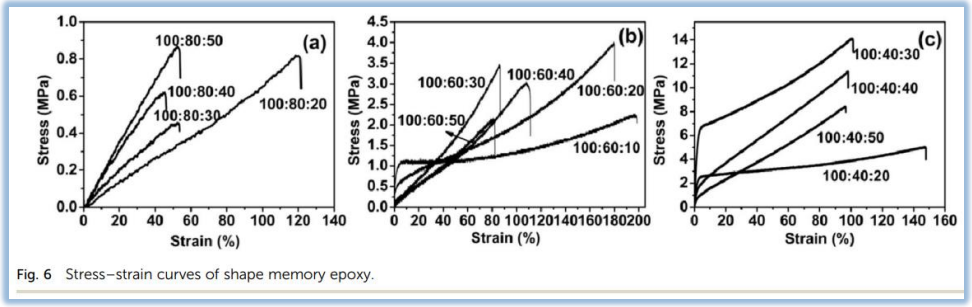


Fig. 6 Stress–strain curves of shape memory epoxy.

Table 4 Tensile properties of shape memory epoxy

E44 : PAE-D230 : D230 (molar ratio)	Tensile strength (MPa)
100 : 80 : 10	—
100 : 80 : 20	0.8 ± 0.2
100 : 80 : 30	0.5 ± 0.1
100 : 80 : 40	0.6 ± 0.2
100 : 80 : 50	0.9 ± 0.3
100 : 60 : 10	2.2 ± 0.5
100 : 60 : 20	3.9 ± 0.3
100 : 60 : 30	3.0 ± 0.6
100 : 60 : 40	3.4 ± 0.3
100 : 60 : 50	2.1 ± 0.2
100 : 40 : 10	—
100 : 40 : 20	5.0 ± 0.8
100 : 40 : 30	14.1 ± 1.2
100 : 40 : 40	11.3 ± 1.8
100 : 40 : 50	8.4 ± 1.0

- One epoxy
- Two amines

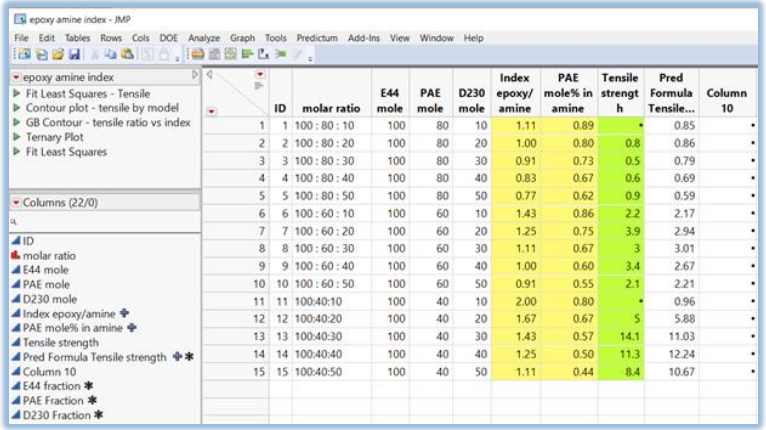
To max. learning:

- Can one quantify (by model) formulation effect on tensile properties?
- Amine ratio effect is elucidated. What about epoxy/amine stoichiometry effect?

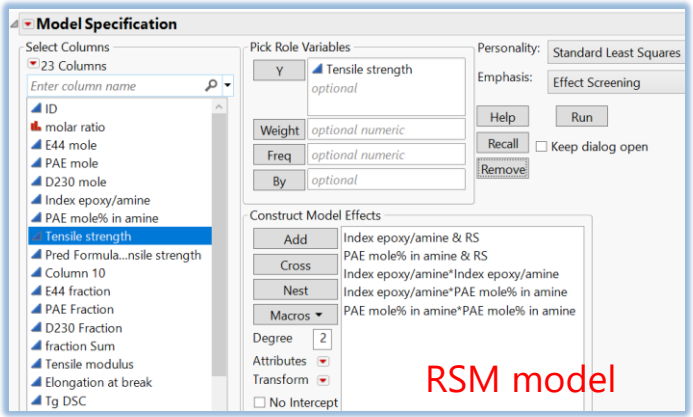
PRE-FORMULATION STAGE

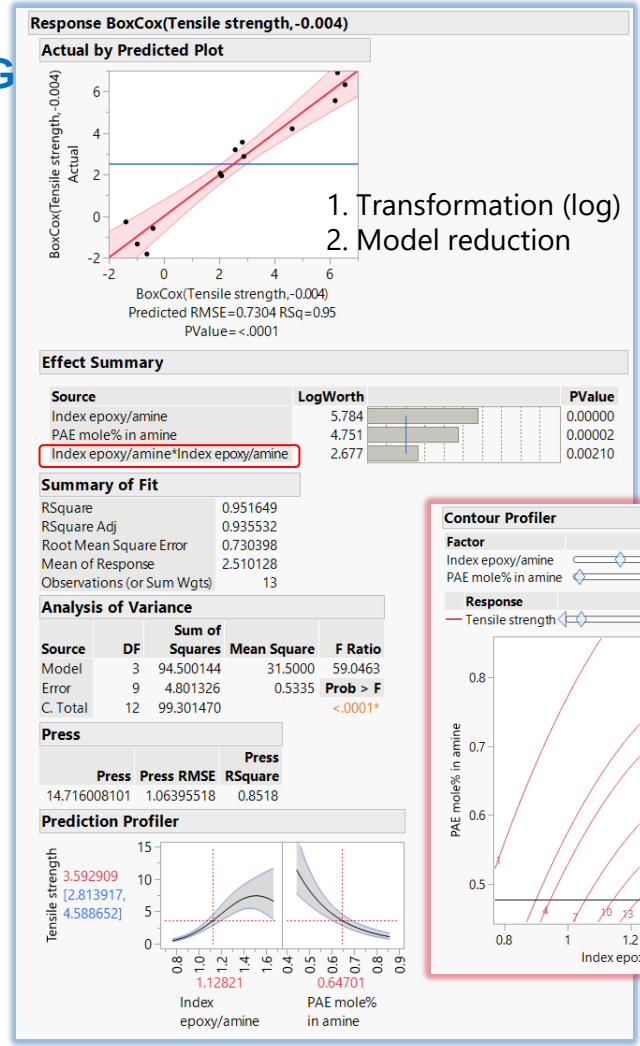
CASE 3: EPOXY LITERATURE LEARNING

epoxy amine index.jmp

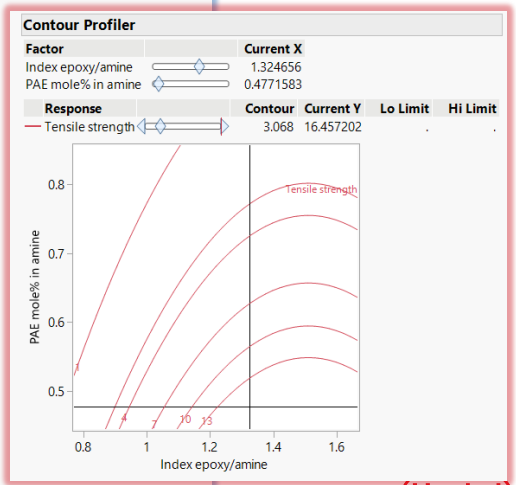


Model with 1) index of epoxy/amine &
2) PAE mole/amine fraction



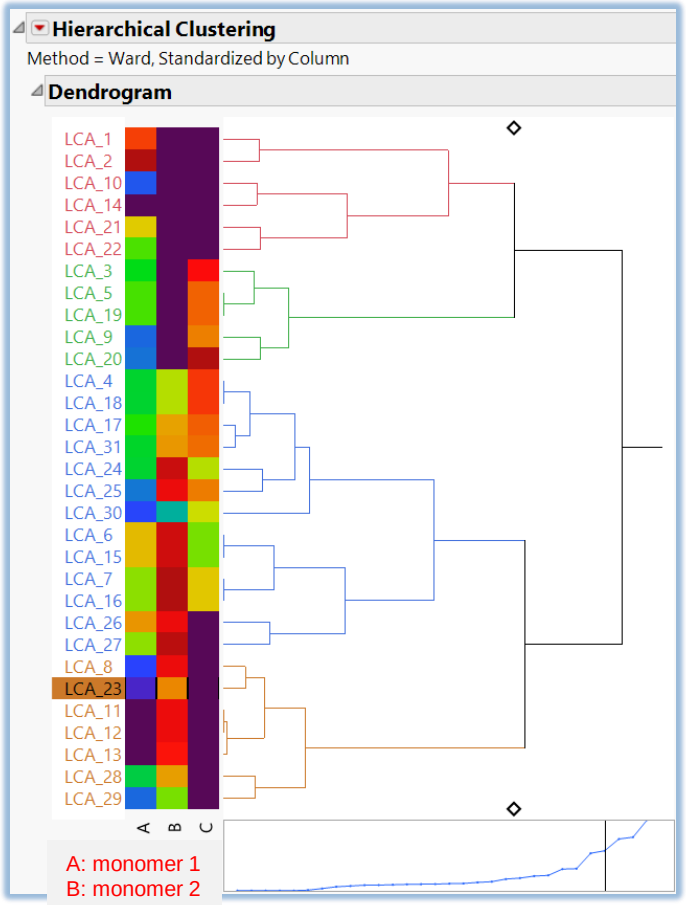


↑ Tensile strength by
↑ index epoxy/amine &
↓ PAE/amine fraction



PRE-FORMULATION STAGE

CASE 4: FORMULATION FAMILY ANALYSIS BY HIERARCHICAL CLUSTERING



Clustering History

Number of Clusters	Distance	Leader	Joiner
30	0.00000	LCA_11	LCA_12
29	0.00014	LCA_5	LCA_19
28	0.00040	LCA_4	LCA_18
27	0.00040	LCA_6	LCA_15
26	0.00047	LCA_7	LCA_16
25	0.03637	LCA_11	LCA_13
24	0.15694	LCA_17	LCA_31
23	0.29215	LCA_8	LCA_23
22	0.34829	LCA_4	LCA_17
21	0.41286	LCA_3	LCA_5
20	0.41966	LCA_28	LCA_29
19	0.44374	LCA_10	LCA_14
18	0.47435	LCA_1	LCA_2
17	0.48811	LCA_21	LCA_22
16	0.49400	LCA_9	LCA_20
15	0.52621	LCA_24	LCA_25
14	0.54235	LCA_8	LCA_11
13	0.62325	LCA_26	LCA_27
12	0.67585	LCA_6	LCA_7
11	0.87447	LCA_3	LCA_9
10	0.95185	LCA_4	LCA_24
9	1.10123	LCA_8	LCA_28
8	1.15347	LCA_4	LCA_30
7	1.62782	LCA_6	LCA_26
6	1.66297	LCA_10	LCA_21
5	2.82621	LCA_4	LCA_6
4	3.02129	LCA_1	LCA_10
3	3.90879	LCA_1	LCA_3
2	4.04964	LCA_4	LCA_8
1	5.35511	LCA_1	LCA_4

5 pairs have very similar formulation

Clustering results depends on factors selection.

FORMULATION STAGE

CASE 5: 2K PU DATA ANALYSIS - TABULATE

Data Courtesy of Dr. Yalin Liu
Worksheet_Gen1.jmp

Local Data Filter

Clear | Favorites

119 matching rows

Inverse

ID (79)

MO968-L42	68
MO968-L44	57
MO968-L49	29
MO968-L50	55
MO968-L51	51
MO968-L52	25
MO968-L53	25

AND | OR

Tabulate

ID = MO968-L42, MO968-L51

		ID			
		MO968-L42		MO968-L51	
		Date		Date	
		1/5		2/2	2/13
		Batch		Batch	Batch
		3000		400	3000
		Lot#		Lot#	Lot#
		L42_001	L42_002	L51_002	L51_001
Raw Function	**Raw name**	**Sum**	**Sum**	**Sum**	**Sum**
resin	E	20.50	.	.	8.10
	G	14.30	.	.	21.70
	L	.	.	.	5.00
Filler	F	0.50	.	.	0.50
	B	40.00	.	.	40.00
	C	10.00	.	.	10.00
	D	3.00	.	.	3.50
	J	10.64	.	.	6.11
Additive	H	.	.	.	4.00
	I	0.06	.	.	0.09
Hardener	K	65.00	.	.	65.00
Ad pro.	A	1.00	.	.	1.00
P/M characteristics					
Mixing Temp		25.00	60.00	25.00	25.00
Mixing Time		40.00	40.00	5.00	40.00
OH/ISO mixing v/v		4.00	4.00	4.00	4.00
NCO/OH index		1.40	1.40	1.40	1.40
Mixer type (1- Ross, 2-DP, 3-speed)		2.00	2.00	1.00	.
P-item	**Properties**	**Prop. comment**			
1.1	gel time, min	T0	24.00	25.00	29.00	16.00
		38, 1w	32.00	34.00	37.00	22.00
		38, 2w	160.00	160.00	40.00	22.00
		38, 3w	.	.	.	24.00
		38, 4w	.	.	.	24.00
2.1	Tack Free time, min	T0	120.00	120.00	110.00	90.00
		38, 1w	210.00	210.00	130.00	100.00
		38, 2w	300.00	300.00	140.00	100.00
		38, 3w	.	.	.	100.00
		38, 4w	.	.	.	100.00
3.1	Viscosity, 2rpm	T0	30400.00	32800.00	72000.00	87200.00
	Viscosity, 10rpm	T0	26080.00	26720.00	44000.00	58400.00

Batch ID, lot#, size, date, ..

Only display ingredients used in selected formula

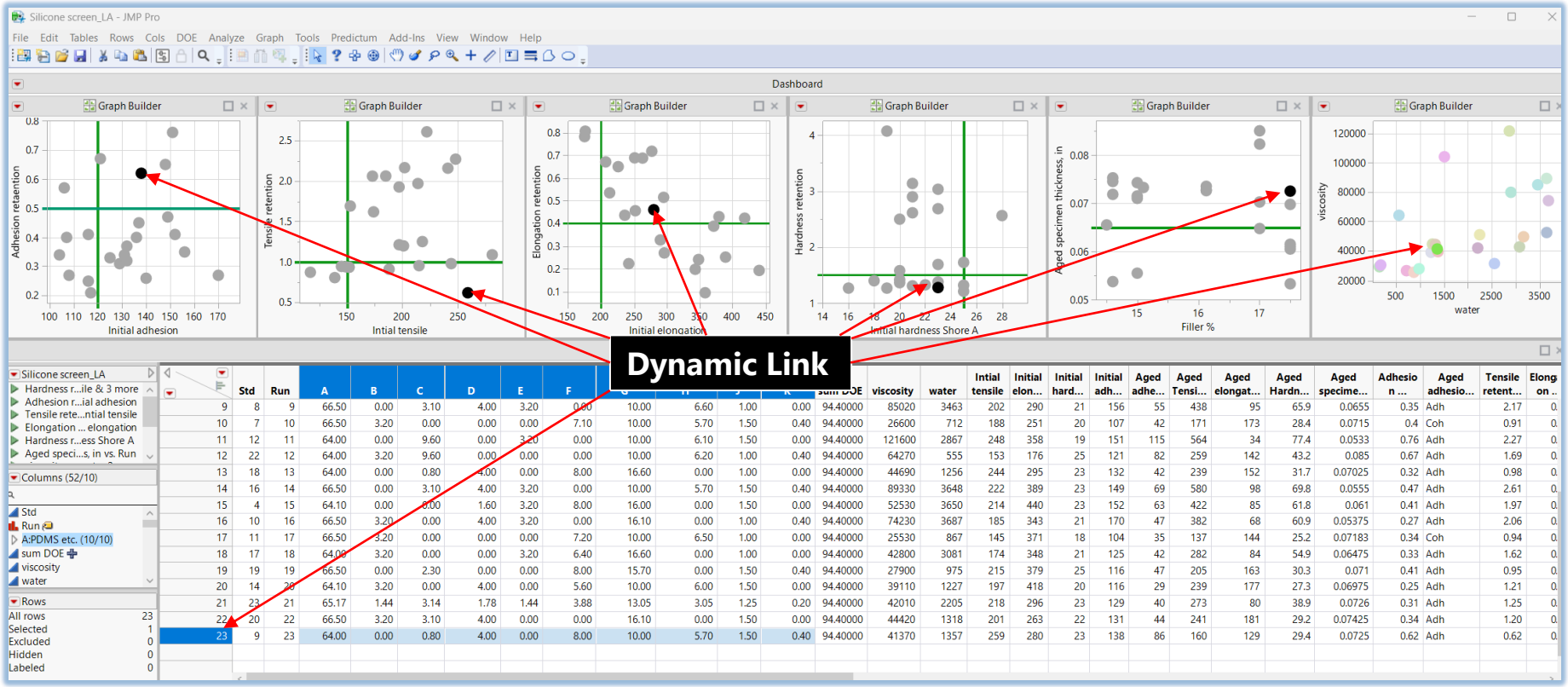
Process & material characteristics

Results & Aging stability

Data Courtesy of Mr. Chris Verosky
Silicone screen_LA.jmp

FORMULATION STAGE

CASE 6: SILICONE DATA ANALYSIS – GRAPHS & TABLE



	Std	Run	A	B	C	D	E	F	G	H	J	K	sum DOE	viscosity	water	Intial tensile	Initial elon...	Initial hard...	Initial adh...	Aged adhe...	Aged Tensi...	Aged elongat...	Aged Hardn...	Aged specime...	Adhesion ...	Aged adhesio...	Tensile retent...	Elong on ..
9	8	9	66.50	0.00	3.10	4.00	3.20	0.00	10.00	6.60	1.00	0.00	94.40000	85020	3463	202	290	21	156	55	438	95	65.9	0.0655	0.35	Adh	2.17	0.
10	7	10	66.50	3.20	0.00	0.00	0.00	7.10	10.00	5.70	1.50	0.00	94.40000	26600	712	188	251	20	107	42	171	173	28.4	0.0715	0.4	Coh	0.91	0.
11	12	11	64.00	0.00	9.60	0.00	3.20	0.00	10.00	6.10	1.50	0.00	94.40000	121600	2867	248	358	19	151	115	564	34	77.4	0.0533	0.76	Adh	2.27	0.
12	22	12	64.00	3.20	9.60	0.00	0.00	0.00	10.00	6.20	1.00	0.40	94.40000	64270	555	153	176	25	121	82	259	142	43.2	0.085	0.67	Adh	1.69	0.
13	18	13	64.00	0.00	0.80	4.00	0.00	8.00	16.60	0.00	1.00	0.00	94.40000	44690	1256	244	295	23	132	42	239	152	31.7	0.07025	0.32	Adh	0.98	0.
14	16	14	66.50	0.00	3.10	4.00	3.20	0.00	10.00	5.70	1.50	0.40	94.40000	89330	3648	222	389	23	149	69	580	98	69.8	0.0555	0.47	Adh	2.61	0.
15	4	15	64.10	0.00	0.00	1.60	3.20	8.00	16.00	0.00	1.50	0.00	94.40000	52530	3650	214	440	23	152	63	422	85	61.8	0.061	0.41	Adh	1.97	0.
16	10	16	66.50	3.20	0.00	4.00	3.20	0.00	16.10	0.00	1.00	0.40	94.40000	74230	3687	185	343	21	170	47	382	68	60.9	0.05375	0.27	Adh	2.06	0.
17	11	17	66.50	3.20	0.00	0.00	0.00	7.20	10.00	6.50	1.00	0.00	94.40000	25530	867	145	371	18	104	35	137	144	25.2	0.07183	0.34	Coh	0.94	0.
18	17	18	64.00	3.20	0.00	0.00	3.20	6.40	16.60	0.00	1.00	0.00	94.40000	42800	3081	174	348	21	125	42	282	84	54.9	0.06475	0.33	Adh	1.62	0.
19	19	19	66.50	0.00	2.30	0.00	0.00	8.00	15.70	0.00	1.50	0.40	94.40000	27900	975	215	379	25	116	47	205	163	30.3	0.071	0.41	Adh	0.95	0.
20	14	20	64.10	3.20	0.00	4.00	0.00	5.60	10.00	6.00	1.50	0.00	94.40000	39110	1227	197	418	20	116	29	239	177	27.3	0.06975	0.25	Adh	1.21	0.
21	23	21	65.17	1.44	3.14	1.78	1.44	3.88	13.05	3.05	1.25	0.20	94.40000	42010	2205	218	296	23	129	40	273	80	38.9	0.0726	0.31	Adh	1.25	0.
22	20	22	66.50	3.20	3.10	4.00	0.00	0.00	16.10	0.00	1.50	0.00	94.40000	44420	1318	201	263	22	131	44	241	181	29.2	0.07425	0.34	Adh	1.20	0.
23	9	23	64.00	0.00	0.80	4.00	0.00	8.00	10.00	5.70	1.50	0.40	94.40000	41370	1357	259	280	23	138	86	160	129	29.4	0.0725	0.62	Adh	0.62	0.

Data Courtesy of Dr. Weiyu Zhang

FORMULATION STAGE

CASE 7: DMA ANALYTICAL INSTRUMENT- MODULUS VS TEMPERATURE

ECF DMA 2023-7-28 - JMP

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

ECF DMA 2023-7-28
- Medium A...e vs. Temp
- GB - E' & ...ta vs. Temp
- GB - DMA 2
- 2023-7-28

Columns (23/0)
- Sample ✱
- Temp (C)
- E' (Pa)
- Tan delta
- na

Rows

All rows	23,932
Selected	0
Excluded	0
Hidden	0
Labeled	0

	Sample	Temp (C)	E' (Pa)	Tan delta
	3366	302	14.9G	0.54
	561E			
	CF3350			
	561E-GF-Lab			
	F17.1 - High Ag			
	69 others	-58.1	7.83M	-9.2m
1	F16.1 - Med. Ag	-39.55	5696700900	0.0148
2	F16.1 - Med. Ag	-38.87	5906559000	0.0069
3	F16.1 - Med. Ag	-37.58	5800772100	0.0151
4	F16.1 - Med. Ag	-36.66	5732715500	0.0098
5	F16.1 - Med. Ag	-35.43	5990764000	0.0141
6	F16.1 - Med. Ag	-34.55	6026911200	0.0119
7	F16.1 - Med. Ag	-34.10	5890096600	0.0114
8	F16.1 - Med. Ag	-32.79	5713266700	0.0139
9	F16.1 - Med. Ag	-31.29	5889757200	0.0123
10	F16.1 - Med. Ag	-30.21	5723090400	0.0092
11	F16.1 - Med. Ag	-29.13	5876573200	0.0096

Local Data Filter

Clear | Favorites

950 matching rows

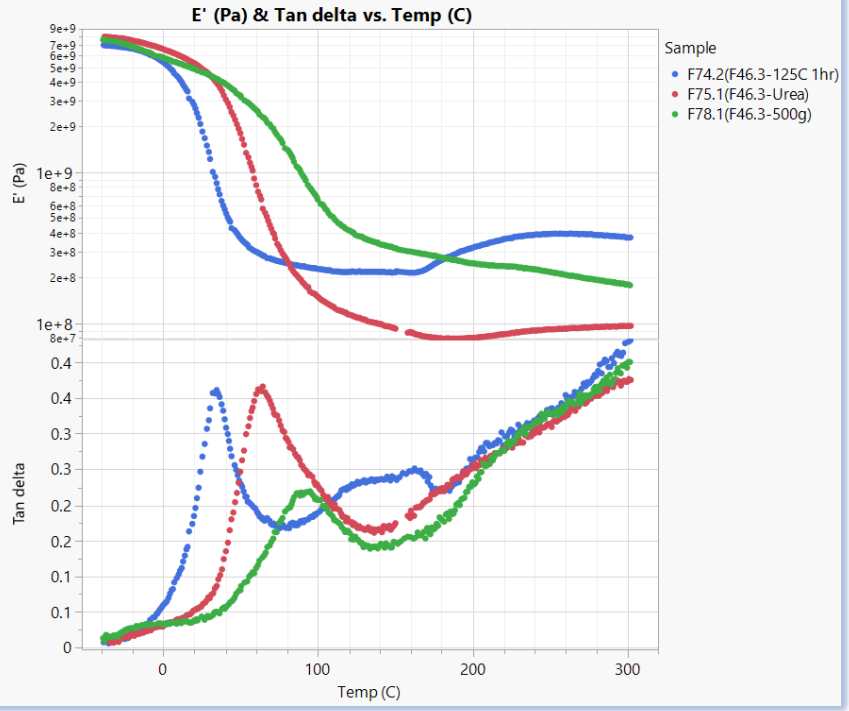
Inverse

Sample (74)

F61.1(F46.3)	314
F61.2(F42.2)	248
F74.2(F46.3-125C 1hr)	309
F75.1(F46.3-Urea)	328
F78.1(F46.3-500g)	313

AND | OR

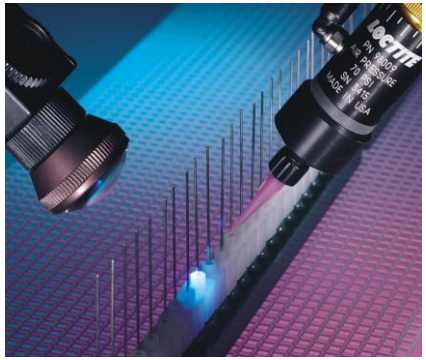
Graph Builder

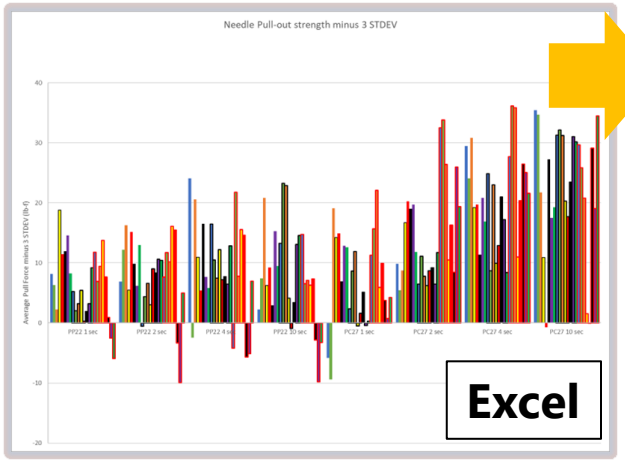


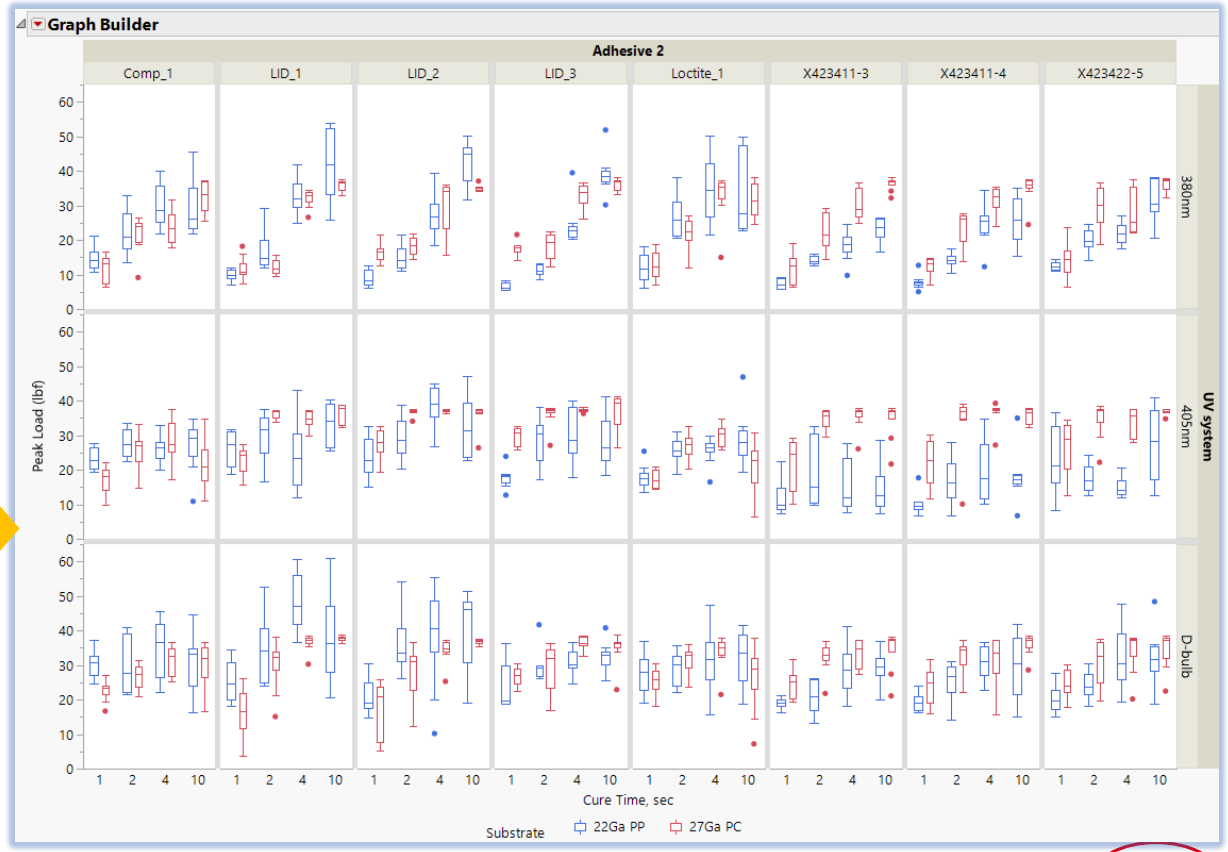
FORMULATION STAGE

CASE 8: LCA VISUAL DATA ANALYSIS - NEEDLE BONDING

Data Courtesy of Mr. Tom Silva







FORMULATION STAGE

CASE 9: EPOXY SHELF-LIFE STUDY

Data Courtesy of Dr. Zhongwei Liu

		Room Temperature STM 700									65 C (149 F) STM 700				
		TS-101 Steel Lapshear					TS-545 FPL ETCH Aluminum					TS-101 Steel Lapshear			
		Specimen label	Width	Overlap	Tensile stress at Maximum Load	Failure Mode	Specimen label	Width	Overlap	Tensile stress at Maximum Load	Failure Mode	Specimen label	Width	Overlap	Tensile stress at Maximum Load	Failure Mode
		UNIT	(in)	(in)	(PSI)		UNIT	(in)	(in)	(PSI)						
		39-2-1	1.00	0.555	4070	adh/coh	39-2-1	1.00	0.500	4150	coh/a				50	adh
		39-2-2	1.00	0.500	4260	adh	39-2-2	1.00	0.483	4300	adh/c				40	adh/coh
		39-2-3	1.00	0.485	4270	adh	39-2-3	1.00	0.570	4190	coh/a				30	adh
		AVG	N/A	0.513	4200	N/A	AVG	N/A	0.518	4213	N/A				27	N/A
		STDDEV	N/A	0.037	113	N/A	STDDEV	N/A	0.046	78	N/A	STDDEV	N/A	0.007	117	N/A
		40-2-1	1.00	0.637	4280	adh	40-2-1	1.00	0.610	4310	adh/coh	40-2-1	1.00	0.545	1660	adh
		40-2-2	1.00	0.509	4340	adh/coh	40-2-2	1.00	0.565	4280	coh/adh	40-2-2	1.00	0.730	1580	adh
		40-2-3	1.00	0.599	4170	adh	40-2-3	1.00	0.585	4250	adh/coh	40-2-3	1.00	0.647	1750	adh
	2wk aged formulation	AVG	N/A	0.582	4263	N/A	AVG	N/A	0.587	4280	N/A	AVG	N/A	0.641	1663	N/A
		STDDEV	N/A	0.066	86	N/A	STDDEV	N/A	0.023	30	N/A	STDDEV	N/A	0.093	85	N/A
		41-2-1	1.00	0.549	3880	adh/coh	41-2-1	1.00	0.563	4480	adh/coh	41-2-1	1.00	0.615	1880	adh
		41-2-2	1.00	0.519	4220	adh/coh	41-2-2	1.00	0.544	4450	adh	41-2-2	1.00	0.562	1390	adh
		41-2-3	1.00	0.568	4390	adh	41-2-3	1.00	0.550	4350	adh	41-2-3	1.00	0.565	1470	adh
		AVG	N/A	0.545	4163	N/A	AVG	N/A	0.552	4427	N/A	AVG	N/A	0.581	1580	N/A
		STDDEV	N/A	0.025	260	N/A	STDDEV	N/A	0.010	68	N/A	STDDEV	N/A	0.030	263	N/A
		42-2-1	1.00	0.580	4030	adh	42-2-1	1.00	0.501	4920	adh/coh	42-2-1	1.00	0.607	2030	adh
		42-2-2	1.00	0.595	4380	adh	42-2-2	1.00	0.517	4270	adh/coh	42-2-2	1.00	0.540	1800	adh
		42-2-3	1.00	0.549	4380	adh/coh	42-2-3	1.00	0.555	4460	adh	42-2-3	1.00	0.548	1990	adh
		AVG	N/A	0.575	4263	N/A	AVG	N/A	0.524	4550	N/A	AVG	N/A	0.565	1940	N/A
		STDDEV	N/A	0.023	202	N/A	STDDEV	N/A	0.028	334	N/A	STDDEV	N/A	0.037	123	N/A
		39-4-1	1.00	0.537	4330	adh/coh	39-4-1	1.00	0.525	4360	adh/coh	39-4-1	1.00	0.530	894	adh
		39-4-2	1.00	0.525	3950	adh	39-4-2	1.00	0.545	4270	adh/coh	39-4-2	1.00	0.520	1530	adh
		39-4-3	1.00	0.555	3760	adh	39-4-3	1.00	0.513	4170	adh/coh	39-4-3	1.00	0.535	1840	adh
		AVG	N/A	0.539	4013	N/A	AVG	N/A	0.528	4267	N/A	AVG	N/A	0.528	1421	N/A
		STDDEV	N/A	0.015	290	N/A	STDDEV	N/A	0.016	95	N/A	STDDEV	N/A	0.008	482	N/A
		40-4-1	1.00	0.590	4260	adh/coh	40-4-1	1.00	0.585	4250	adh/coh	40-4-1	1.00	0.578	1250	adh
		40-4-2	1.00	0.545	4200	adh	40-4-2	1.00	0.535	4410	adh/coh	40-4-2	1.00	0.545	1240	adh
		40-4-3	1.00	0.560	4140	adh	40-4-3	1.00	0.544	4420	adh/coh	40-4-3	1.00	0.575	1390	adh
	4wks aged formulation	AVG	N/A	0.565	4200	N/A	AVG	N/A	0.555	4360	N/A	AVG	N/A	0.566	1293	N/A
		STDDEV	N/A	0.023	60	N/A	STDDEV	N/A	0.027	95	N/A	STDDEV	N/A	0.018	84	N/A
		41-4-1	1.00	0.488	4330	adh	41-4-1	1.00	0.620	4370	adh/coh	41-4-1	1.00	0.570	1370	adh
		41-4-2	1.00	0.538	4340	adh/coh	41-4-2	1.00	0.521	4450	adh/coh	41-4-2	1.00	0.511	1450	adh
		41-4-3	1.00	0.451	4440	adh/coh	41-4-3	1.00	0.581	4600	adh	41-4-3	1.00	0.540	1550	adh
		AVG	N/A	0.492	4370	N/A	AVG	N/A	0.574	4473	N/A	AVG	N/A	0.540	1457	N/A
		STDDEV	N/A	0.044	61	N/A	STDDEV	N/A	0.050	117	N/A	STDDEV	N/A	0.030	90	N/A

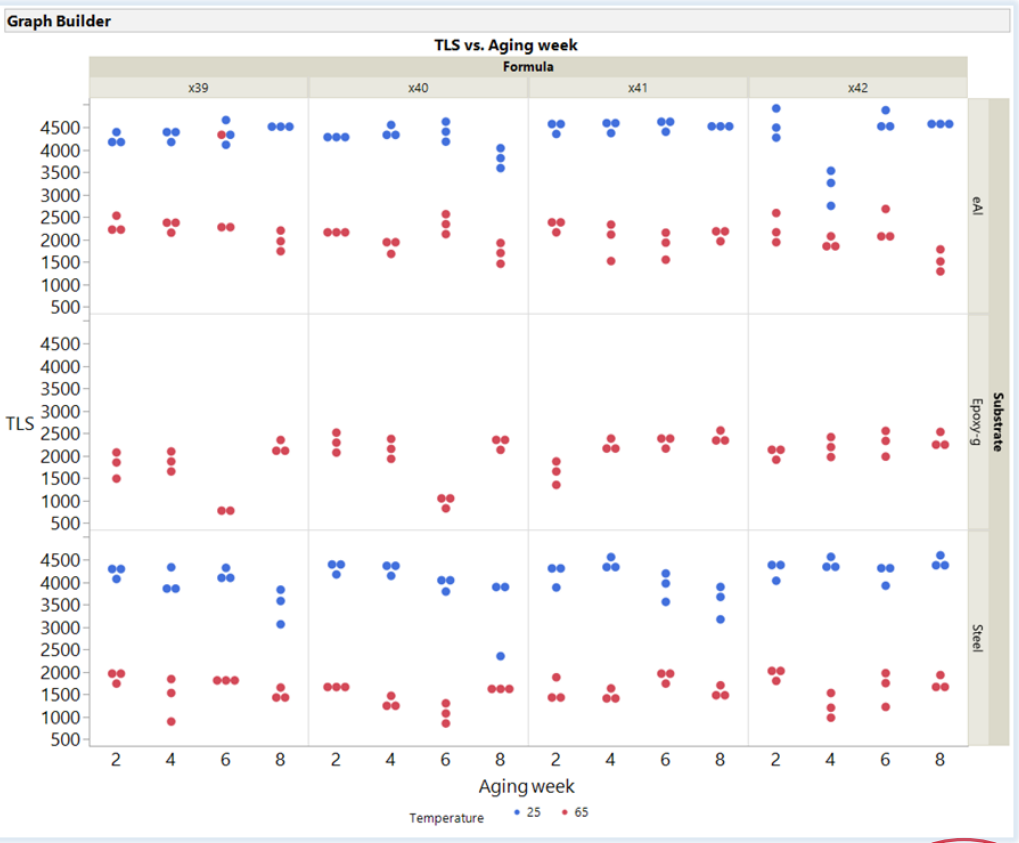
Excel

1.epoxy aging data - JMP

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

1.epoxy aging data

	ID	Formula	Substrate	Replicate	Aging week	Temperat...	TLS
1	2039/02/01	x39	Steel	1	2	25	4070
2	2039/02/02	x39	Steel	2	2	25	4260
3	2039/02/03	x39	Steel	3	2	25	4270
4	2040/02/01	x40	Steel	1	2	25	4280
5	2040/02/02	x40	Steel	2	2	25	4340



FORMULATION STAGE

CASE 10: CATALYST MIXTURE OPTIMIZATION

10-run face-center CCD design

Cat CCD - JMP

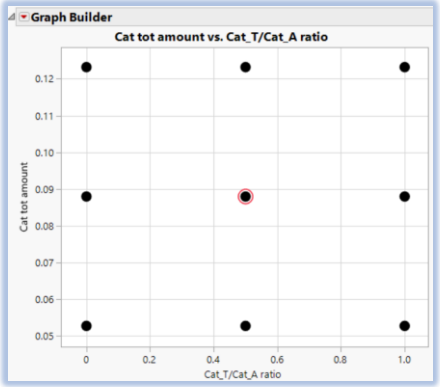
File Edit Tables Rows Cols DOE Analyze Graph Tools Predictum Add-Ins View Windo

Cat CCD
Design Central Composite Des
Model
Evaluate Design
DOE Dialog
Design spac...t vs cat ratio
Fit Model
FM ^-0.5
Contour Pro...Pot life (min)

Columns (7/0)
Pattern
Cat_T/Cat_A ratio *
Cat tot amount *
Pot life (min) *
Pred Formula Pot life (min)

	Pattern	Cat_T/Cat_A ratio	Cat tot amount	Pot life (min)	Pred Formula Pot life (min)
1	−−	0	0.0528	40.57	38.50
2	−+	0	0.1232	6	5.95
3	a0	0	0.088	11	11.45
4	0a	0.5	0.0528	87	95.46
5	0A	0.5	0.1232	14.5	14.52
6	00	0.5	0.088	26.53	27.06
7	00	0.5	0.088	29.13	27.06
8	+−	1	0.0528	79	78.04
9	++	1	0.1232	28.9	29.41
10	A0	1	0.088	40.2	39.72

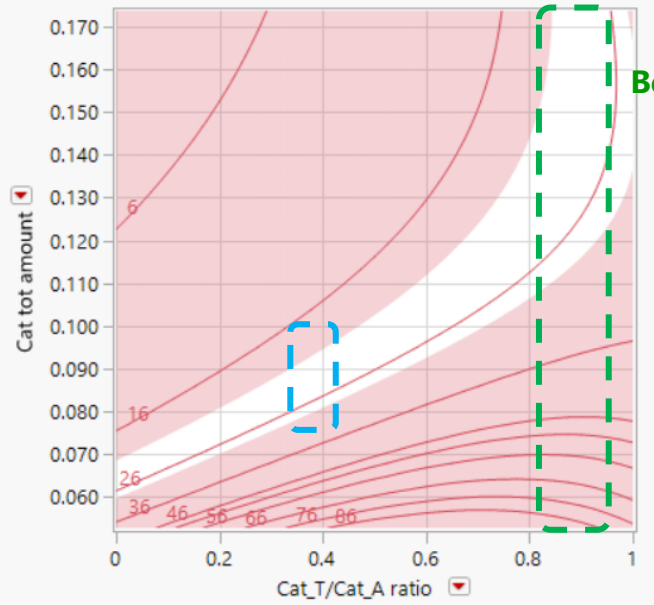
Graph Builder



Contour Profiler

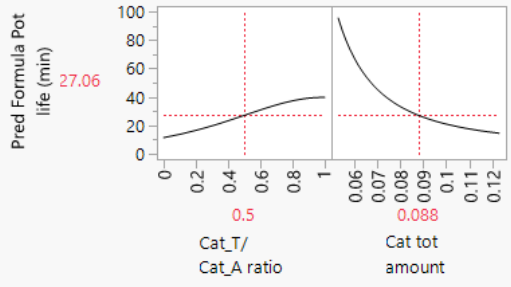
Factor	Current X
Cat_T/Cat_A ratio	1
Cat tot amount	0.0528

Response	Contour	Current Y	Lo Limit	Hi Limit
Pred Formula Pot life (min)	50	78.037536	20	28



Better Robustness

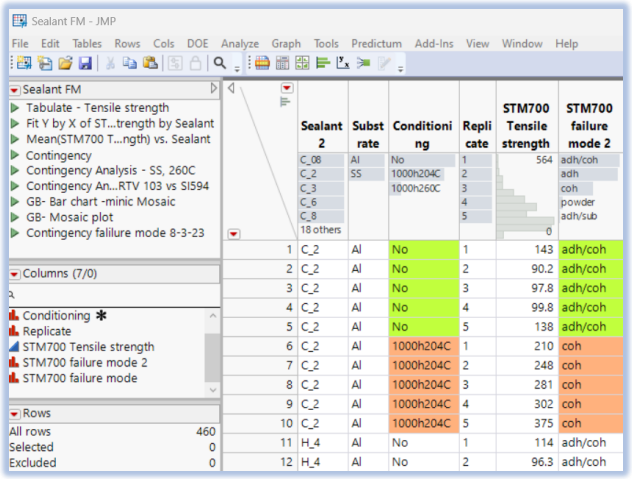
Prediction Profiler

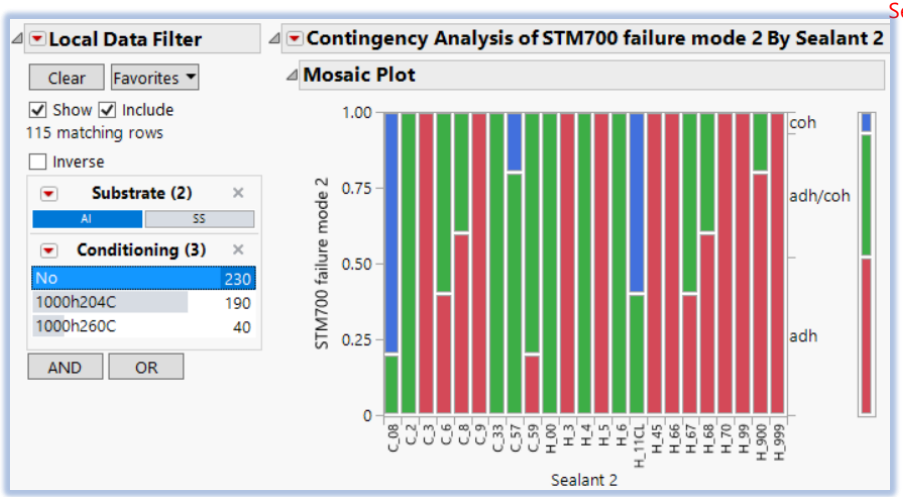


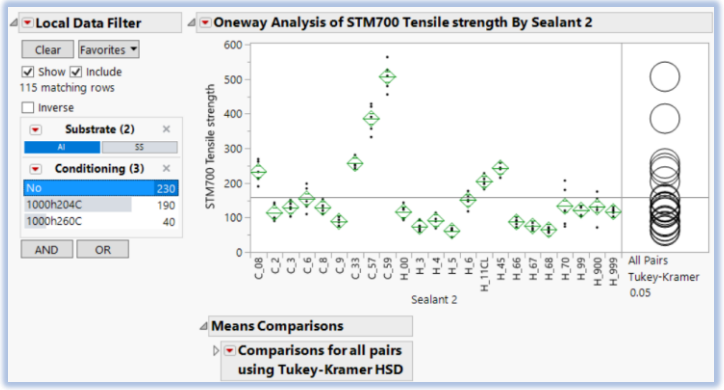
Data Courtesy of Mr. Tim Graver
Sealant FM.jmp

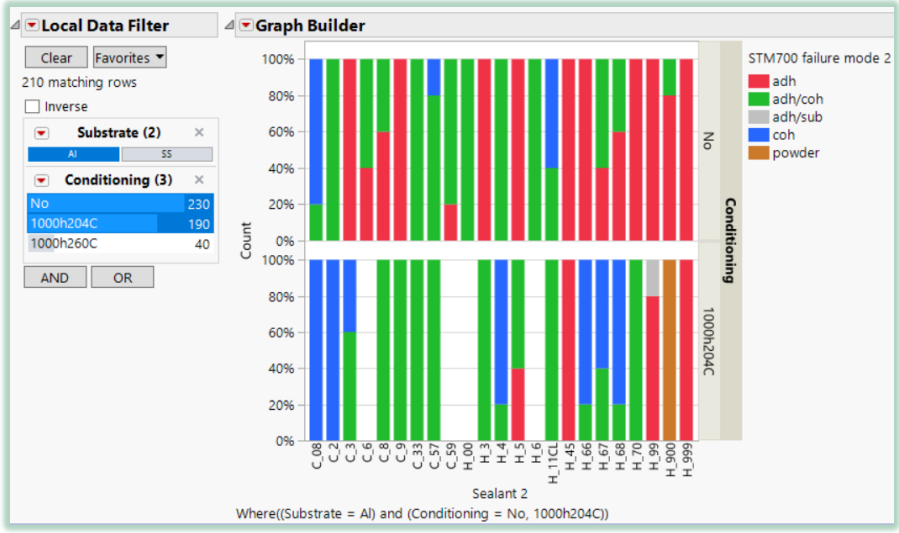
FORMULATION STAGE

CASE 11: FAILURE MODE ANALYSIS









FORMULATION & APPLICATION STAGE

CASE 12: PROCESSING STUDY - SPRAYABLE SEALANT

Case:

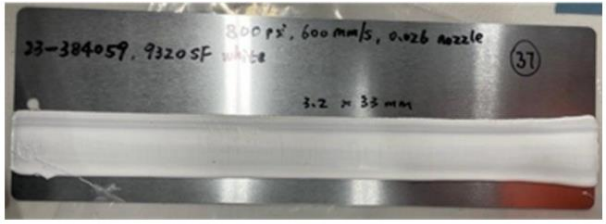
- A sprayable sealant is used to protect metal joints.
- The sprayed beads need to satisfy dimension spec and surface quality
- Spray processing parameters and sealant viscosity affect spraying results.
- Experiments (38 runs) were performed not in DOE fashion
- Seek JMP help in guiding project direction

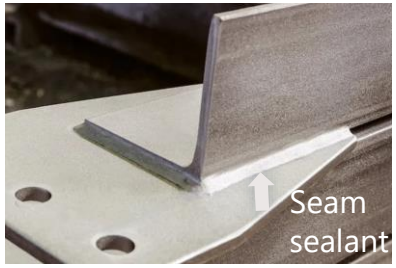
Key Variables:

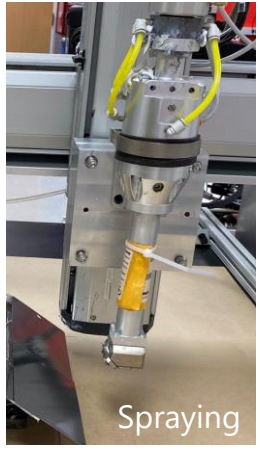
- Spraying pressure
- Spraying nozzle type
- Spray head travel speed
- Sealant viscosity

Measurements:

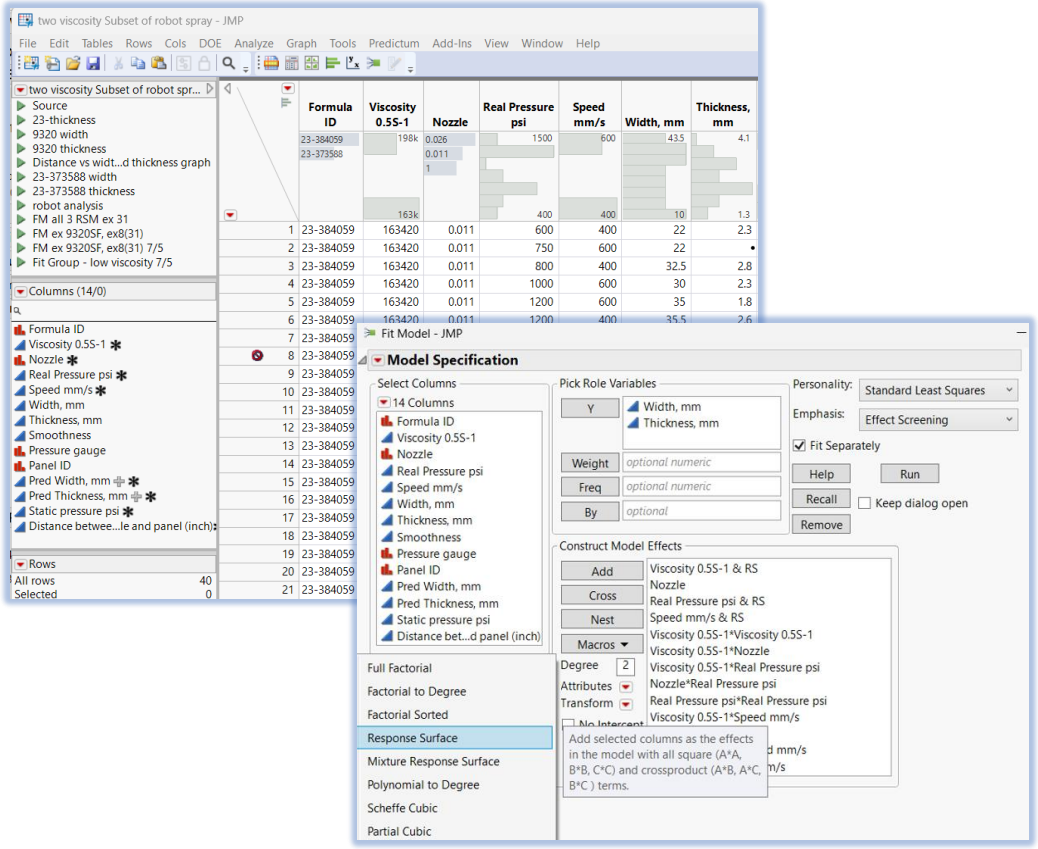
- Deposit width (20-30mm)
- Deposit thickness (2-3mm)







CASE 12: SPRAYABLE SEALANT MODEL REGRESSION



Formula ID	Viscosity 0.5S-1	Nozzle	Real Pressure psi	Speed mm/s	Width, mm	Thickness, mm
1	23-384059	163420	0.011	600	400	22	2.3
2	23-384059	163420	0.011	750	600	22	•
3	23-384059	163420	0.011	800	400	32.5	2.8
4	23-384059	163420	0.011	1000	600	30	2.3
5	23-384059	163420	0.011	1200	600	35	1.8
6	23-384059	163420	0.011	1200	400	35.5	2.6
7	23-384059						
8	23-384059						
9	23-384059						
10	23-384059						
11	23-384059						
12	23-384059						
13	23-384059						
14	23-384059						
15	23-384059						
16	23-384059						
17	23-384059						
18	23-384059						
19	23-384059						
20	23-384059						
21	23-384059						

Width

Summary of Fit

RSquare	0.925068
RSquare Adj	0.91336
Root Mean Square Error	3.0265
Mean of Response	26.95789
Observations (or Sum Wgts)	38

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	3618.5822	723.716	79.0109
Error	32	293.1105	9.160	Prob > F
C. Total	37	3911.6926		<.0001*

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	23.989157	0.525424	45.66	<.0001*
Viscosity 0.5S-1(163420,198360)	-2.523687	0.517961	-4.87	<.0001*
Nozzle[0.011]	2.7546649	0.716668	3.84	0.0005*
Nozzle[0.026]	10.736634	0.717852	14.96	<.0001*
Real Pressure psi(400,1500)	6.4729621	1.027582	6.30	<.0001*
Speed mm/s(400,600)	-1.960255	0.503582	-3.89	0.0005*

Thickness

Summary of Fit

RSquare	0.839695
RSquare Adj	0.81384
Root Mean Square Error	0.279715
Mean of Response	2.583784
Observations (or Sum Wgts)	37

Analysis of Variance

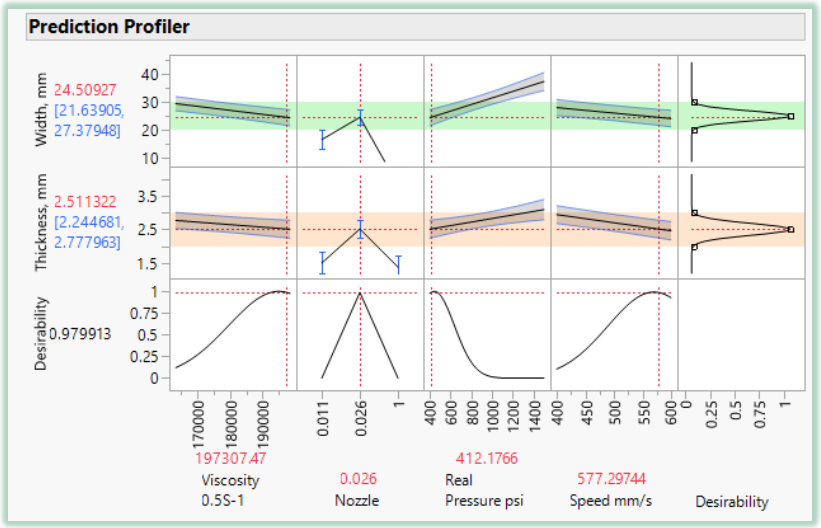
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	12.704820	2.54096	32.4764
Error	31	2.425451	0.07824	Prob > F
C. Total	36	15.130270		<.0001*

Parameter Estimates

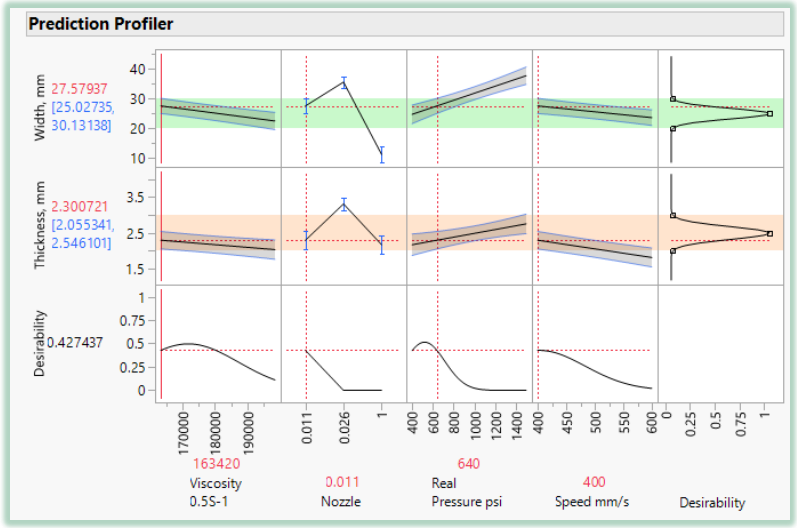
Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	2.3881589	0.04938	48.36	<.0001*
Viscosity 0.5S-1(163420,198360)	-0.130877	0.048455	-2.70	0.0111*
Nozzle[0.011]	-0.294902	0.068364	-4.31	0.0002*
Nozzle[0.026]	0.7167315	0.067508	10.62	<.0001*
Real Pressure psi(400,1500)	0.2910259	0.096183	3.03	0.0050*
Speed mm/s(400,600)	-0.24062	0.047461	-5.07	<.0001*

CASE 12: SPRAY PROCESSING VS FORMULATION VISCOSITY

Higher sealant viscosity



Lower sealant viscosity

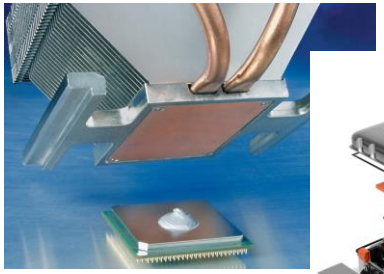


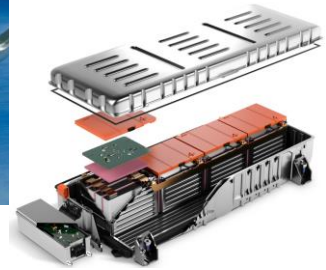
- The spraying conditions need to be adjusted depending on sealant viscosity
  - High η: wider nozzle slot, faster speed
  - Low η: narrower nozzle slot, slower speed

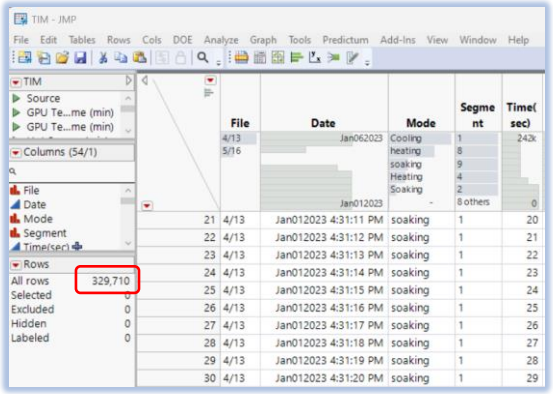
Data Courtesy of Mr. Kunal Rath
TIM.jmp

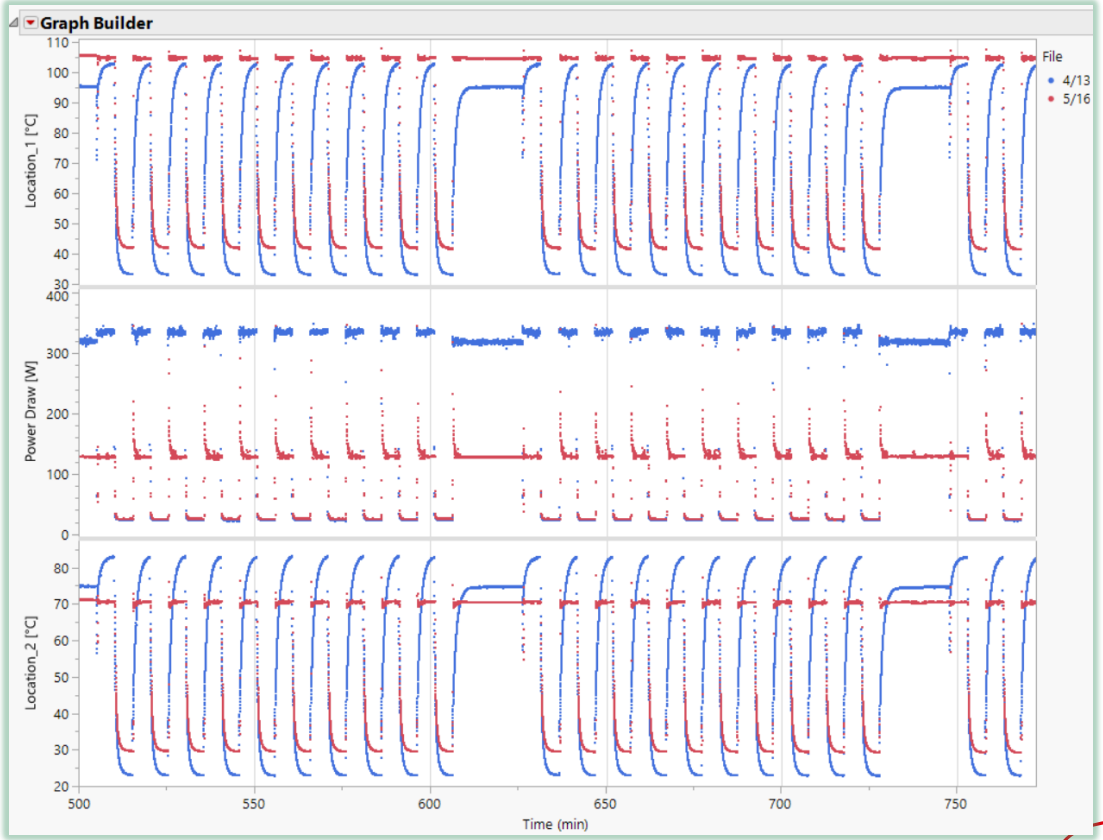
FORMULATION & APPLICATION STAGE

CASE 13: THERMAL PERFORMANCE -THERMAL INTERFACE MATERIALS



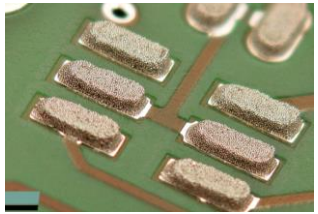






FORMULATION & APPLICATION STAGE

CASE 14: PRINTING DEFECT TROUBLE SHOOTING



Pinting v2 - JMP [2]

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

Pinting v2
Partiti...teel rod
Predict...eening

Columns (8/0)
Print Sample ID
Factor A
Factor B
Factor C
Factor D
Factor E
Factor F
Pinhole rating

Rows
All rows 21

	Print Sample ID	Factor A	Factor B	Factor C	Factor D	Factor E	Factor F	Pinhole rating
1	2020028...	1	No	0.5	6	0.5	No	0
2	2020010...	0.9	No	0.75	6	1	No	0
3	2020010...	0.9	No	1	7	1	No	0
4	2020030...	1	No	0.75	6	1	Yes	3
5	2020030...	0.9	No	0.95	6	1	Yes	3
6	2020030...	0.9	No	1	6	0.8	Yes	3
7	2020030...	0.9	No	0.9	6	0.8	Yes	3
8	2020030...	0.65	No	0.5	6	0.5	Yes	0
9	2020030...	0.75	No	0.75	6	1	Yes	3
10	2020030...	0.85	No	0.9	6	0.8	Yes	3
11	2020030...	0.5	No	0.9	6	0.8	Yes	3

6 factors of processing variables : 21 runs

Partition analysis

Split Prune

RSquare	RASE	N	Number of Splits	AICc
0.422	1.0358648	21	3	75.0754

All Rows

		Logworth	Difference
Count	21		
Mean	1.952381	2.368198	1.8
Std Dev	1.3955712		

Factor F(No)

Count	6
Mean	0.6666667
Std Dev	1.2110601

Candidates

Factor F(Yes)

		Logworth	Difference
Count	15		
Mean	2.4666667	0.5314555	0.7
Std Dev	1.1254629		

Factor B(Yes)

Count	5
Mean	2
Std Dev	1.4142136

Candidates

Factor B(No)

		Logworth	Difference
Count	10		
Mean	2.7	0.1304856	0.6
Std Dev	0.9486833		

Factor C<0.9

Count	5
Mean	2.4
Std Dev	1.3416408

Candidates

Factor C>=0.9

Count	5
Mean	3
Std Dev	0

Candidates

Column Contributions

Term	Number of Splits	SS	Portion
Factor F	1	13.8857143	0.8457
Factor B	1	1.63333333	0.0995
Factor C	1	0.9	0.0548
Factor A	0	0	0.0000
Factor D	0	0	0.0000
Factor E	0	0	0.0000

Predictor screening

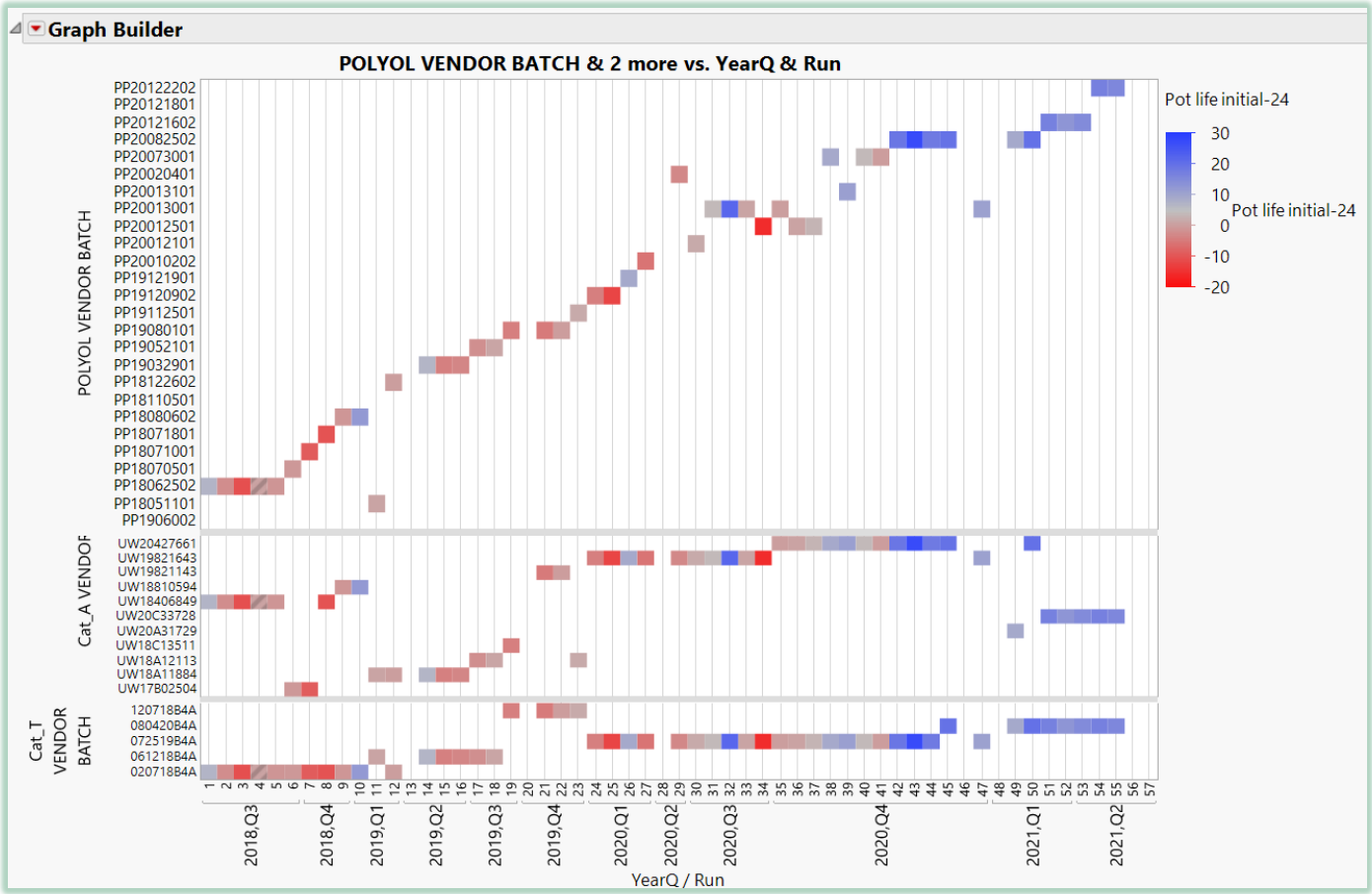
Predictor Screening

	Pinhole rating		
Predictor	Contribution	Portion	Rank
Factor F	7.39516	0.3752	1
Factor D	7.06880	0.3587	2
Factor E	1.98505	0.1007	3
Factor C	1.58876	0.0806	4
Factor A	0.88666	0.0450	5
Factor B	0.78383	0.0398	6

Henkel

SCALE UP & MANUFACTURING STAGE

CASE 15: TROUBLE SHOOTING - LOT-TO-LOT ANALYSIS



BENCHMARK STAGE

CASE 16: SILICONE SEALANT COMPARISON

Data Courtesy of Mr. Tim Graver

Sealant - JMP

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

Sealant
Oneway A...Adhesive 2

Columns (31/0)
Subgroup
Adhesive 2 ✱
Company
Shore A
Tack-free time

Rows
All rows 140
Selected 0
Excluded 0
Hidden 0

	Subgroup	Adhesive 2	Company	Shore A	Tack-free time
4		C_33	Henkel	59	52.5
2		H_3	Competitor		
3		H_5			
6		H_6			
1		H_66			
3 others		18 others		17.5	2.5
1	1	C_2	Competi...	30	7.5
2	1	C_2	Competi...	31	7.5
3	1	C_2	Competi...	30	12.5
4	1	C_2	Competi...	29	•
5	1	C_2	Competi...	29.5	•
6	1	H_4	Henkel	25	12.5
7	1	H_4	Henkel	26	12.5

Sealant - Oneway of Tensile strength by Adhesive 2 2 - JMP

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

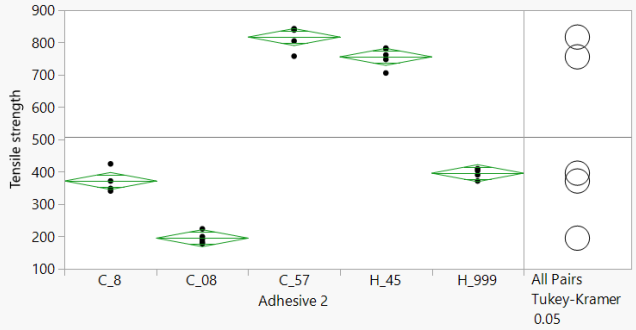
Column Switcher
9 Columns
Shore A
Tack-free time
Tensile strength
Elongation
Al TLS RT
Al TLS 204C 1000hr
Al TLS 260C 1000hr
AL TLS avg retention 204C(%)
AL TLS avg retension 260C(%)

Local Data Filter
Clear Favorites
Show Include
25 matching rows
Inverse
Adhe... (23)

C_2	5
C_3	5
C_6	5
C_8	5
C_08	5
C_9	5
C_33	10
C_57	5
C_59	5
H_3	10
H_4	5
H_5	10
H_6	10
H_11CL	5
H_45	5
H_00	5
H_66	10
H_67	5
H_68	5
H_70	5
H_699	5
H_900	5
H_999	5

AND OR

Oneway Analysis of Tensile strength By Adhesive 2



Oneway Anova
Summary of Fit
Analysis of Variance
Means for Oneway Anova
Means Comparisons
Comparisons for all pairs using Tukey-Kramer HSD
Confidence Quantile

q*	Alpha
2.99238	0.05

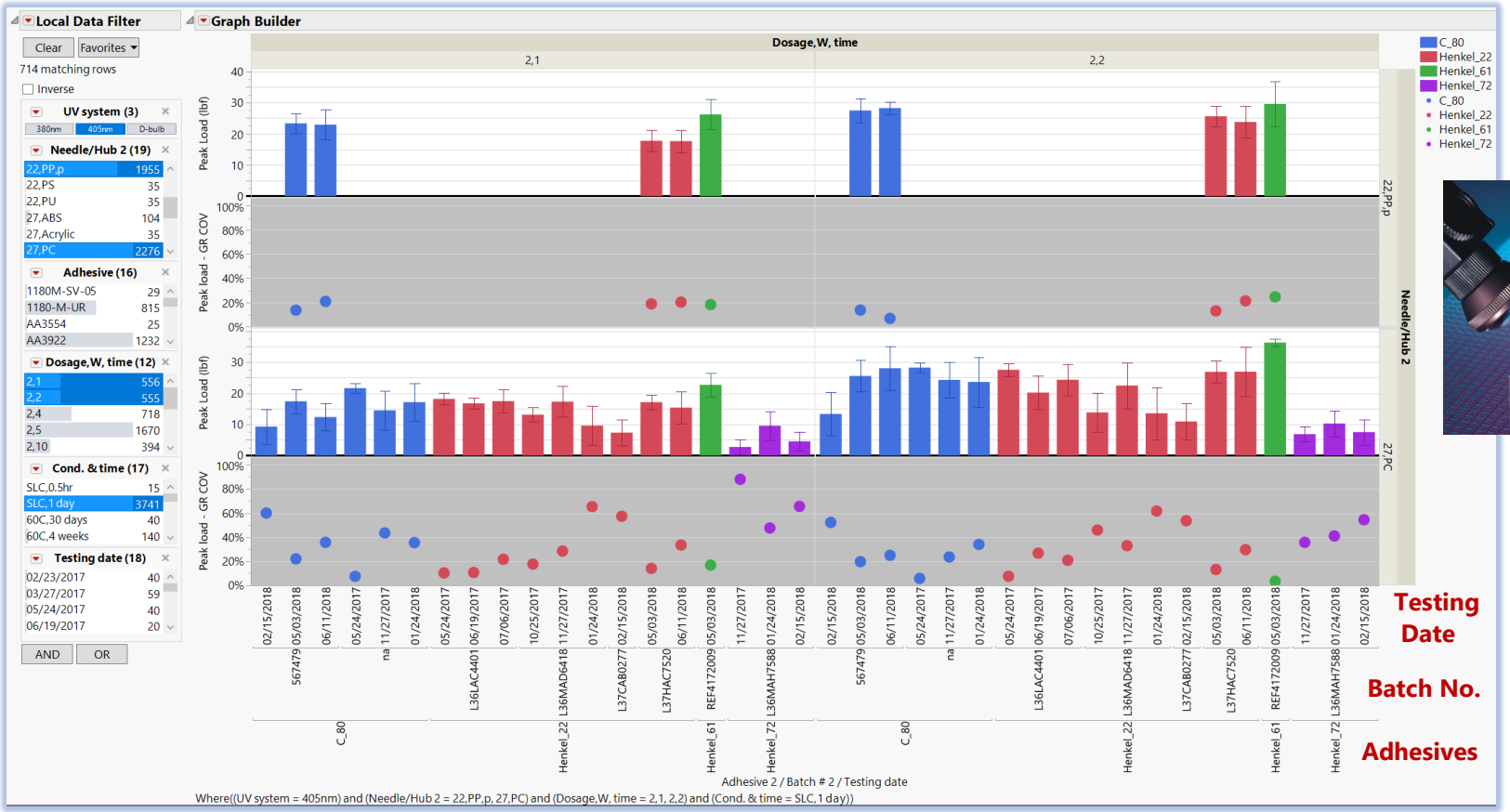
HSD Threshold Matrix
Connecting Letters Report

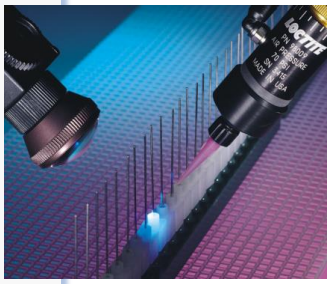
Level		Mean
C_57	A	816.20000
H_45	B	755.00000
H_999	C	395.20000
C_8	C	371.00000
C_08	D	194.20000

Levels not connected by same letter are significantly different.

BENCHMARK STAGE

CASE 17: BATCH CONSISTENCY- LIGHT CURE ADHESIVE COMPARISON





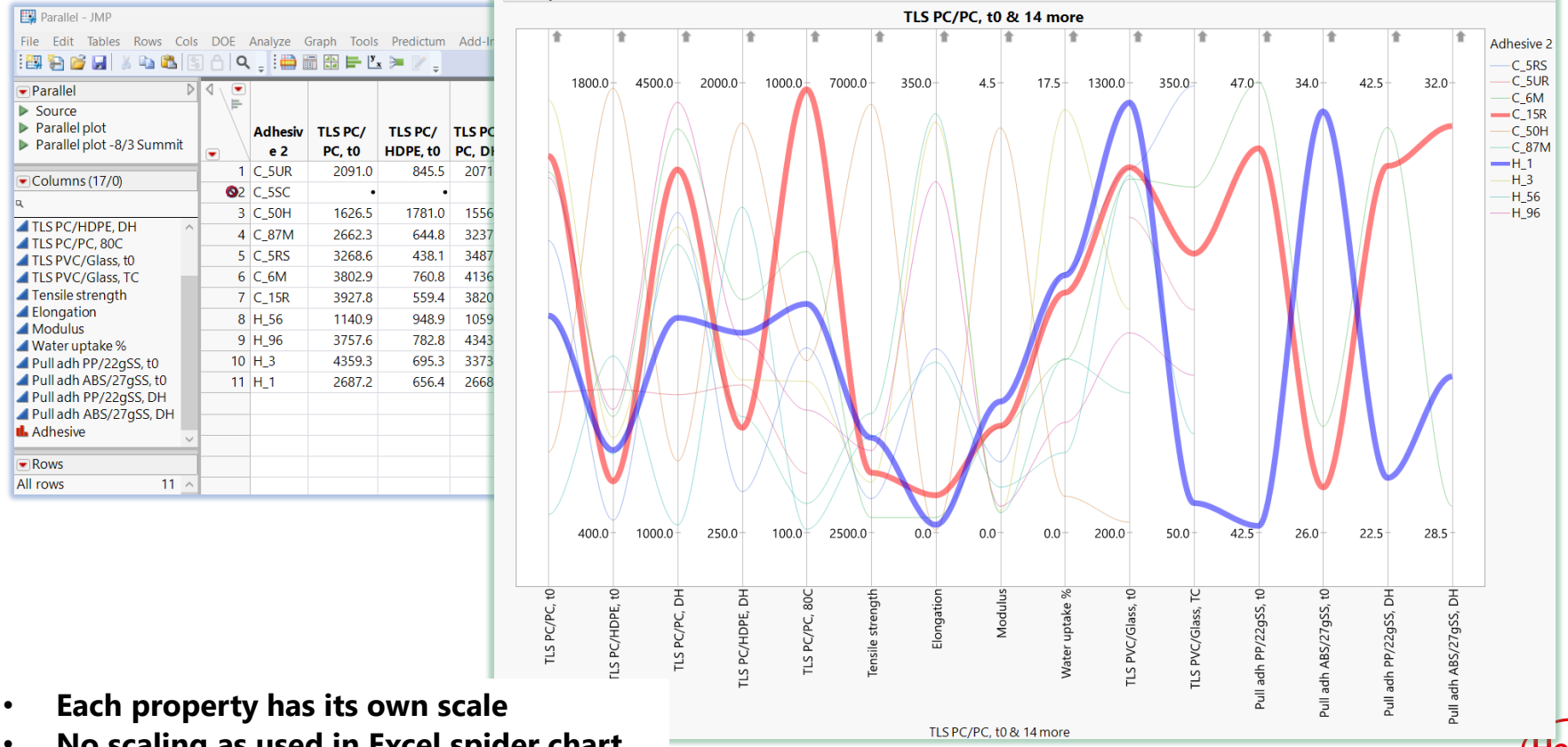
18 reports, various adhesives, multiple lots, various test times

BENCHMARK STAGE

CASE 18: LIGHT CURE ADHESIVE COMPARISON

Data Courtesy of Mr. Andy Messana

Parallel.jmp



- **Each property has its own scale**
- **No scaling as used in Excel spider chart**

JMP-BASED FORMULATION WORKSHEET DEVELOPMENT

Design, Calculate, Record, Analyze … Formulation

Using JMP, Instead of Excel

ADHESIVE FORMULATION CALCULATION

A. One component adhesives (1k)

- No mixing, stable during storage
- Super Glue, RTV, anaerobic, light-cure adhesives, …
- 1k heat cure adhesive like epoxy
  - Stoichiometry (index) :
    molar ratio of epoxy to amine (or acid)

B. Two component adhesives (2K)

- 2k epoxy, 2k polyurethane, 2k silicone, …
- Require mixing by
  - index
  - volume ratio
  - weight ratio
  - typically, combination of index with volume/weight

C. Excel is used in formulation calculation

- Equivalent weight of function group
- Density

FORMULATION WITH EXCEL

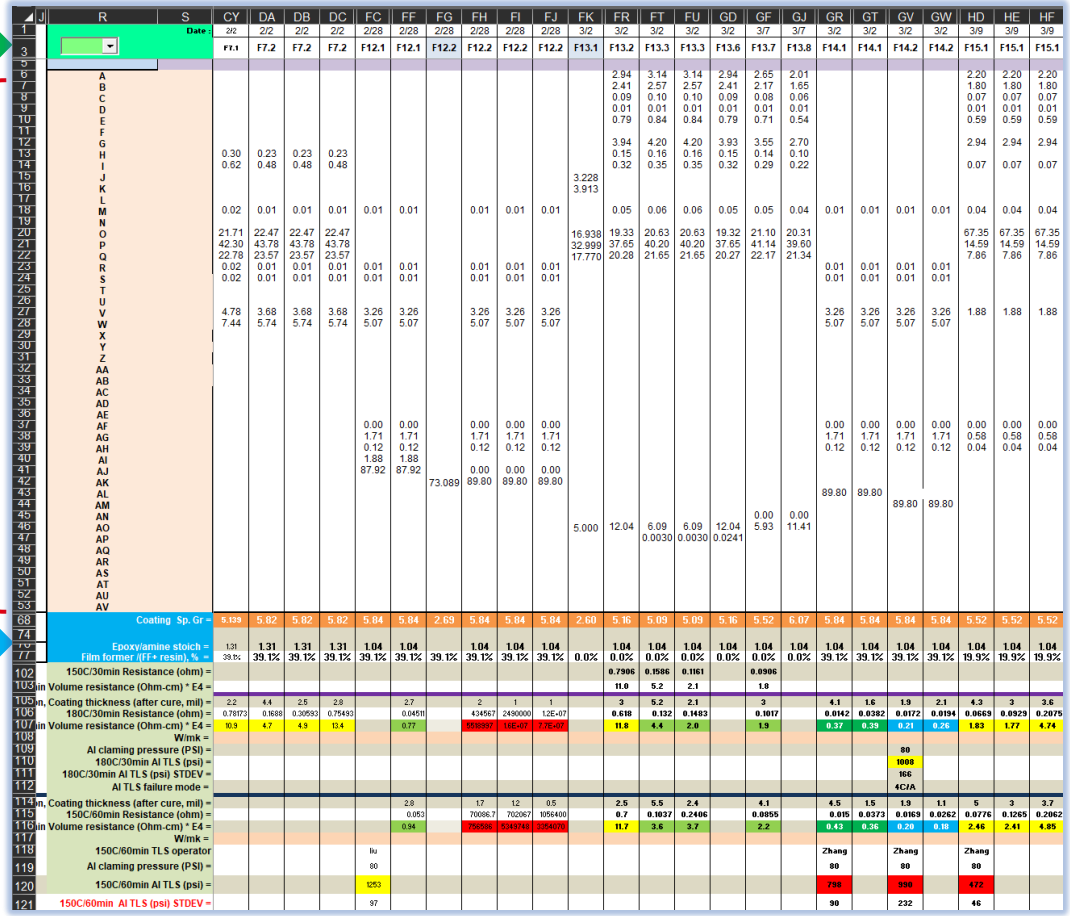
Formula

Heading

Ingredient

Charact. / process

Results



Pros:

- Available to all, easy sharing & communication, no additional training
- Convenience: All data in one column, Mixed data types
- Formulating, calculating, recording, analyzing, … all in the same file

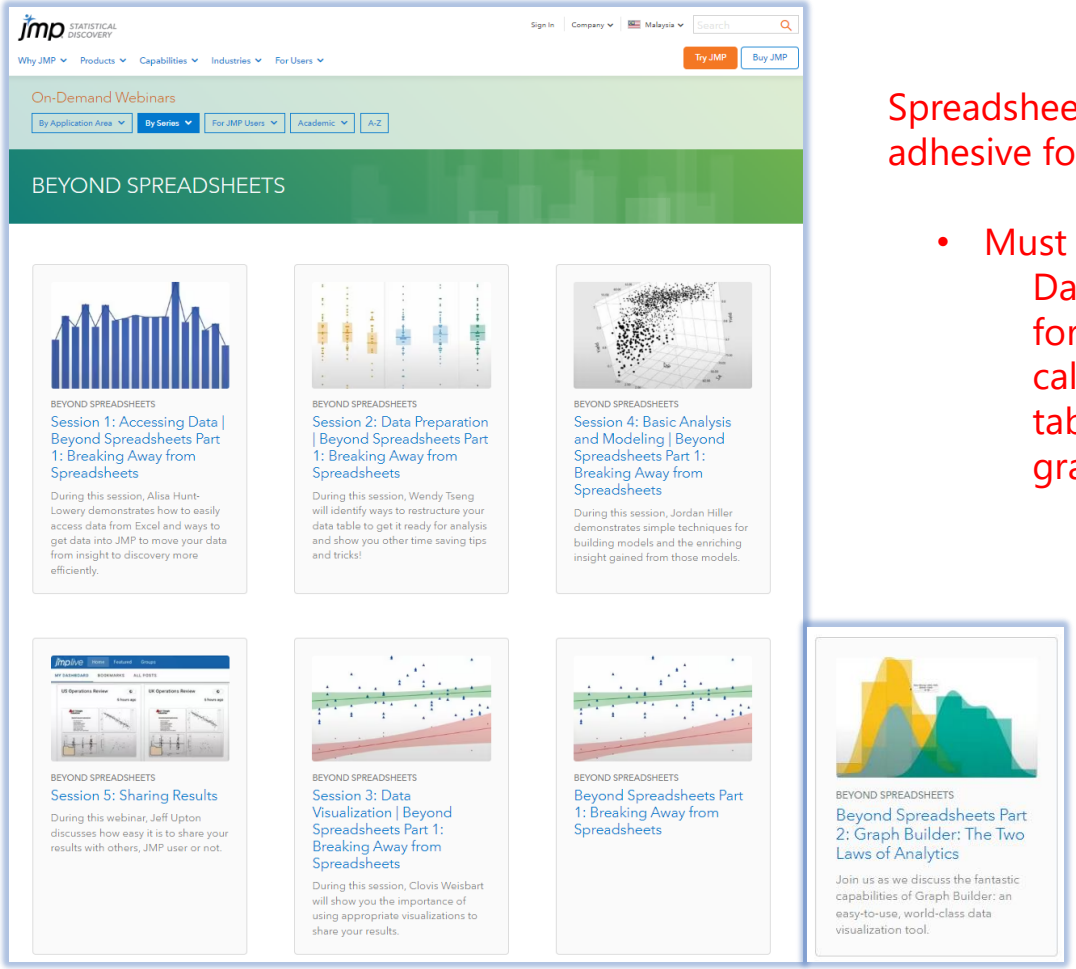
Cons:

- **Need Row matching**
  - Ingredients
  - Test results
  - Long raw list in scouting phase
- **Need to hide columns for easy comparison in large table**
- **Hard to compare in tab-by-tab format**
- **Difficulty in graphing**

JMP WEBINARS: BEYOND SPREADSHEETS

https://www.jmp.com/en_my/events/ondemand/webcasts/by-series/beyond-spreadsheets.html

1. Data access
2. Data preparation
3. Data visualization
4. Basic analysis and modelling
5. Sharing results



Spreadsheet for adhesive formulation:

- Must have
  Data recording, formulation, calculation, tabulating, graphing, …

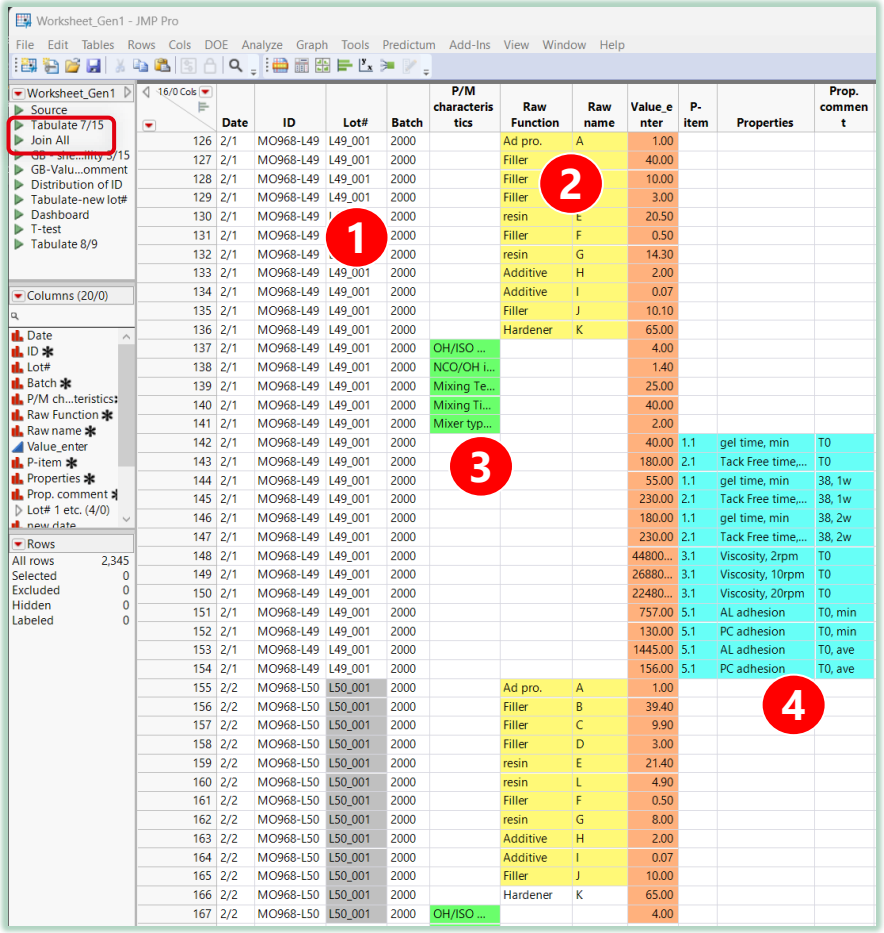
JMP WORKSHEET DEVELOPMENT: OBJECTIVES

- **Broad capability:**
  - **formulation design, calculation, recording, analysis, …**
- **All in one:**
  - **minimize cross-platform copy & paste**
- **Easy operation:**
  - **simple data entry, JSL, virtual link …**
- **ML ready:**
  - **normalized, wide format …**

FORMULATION WORKSHEET – GEN1

CASE 19: FORMULA ENTRY AND ANALYSIS

Data Courtesy of Dr. Yalin Liu
Worksheet_Gen1.jmp



	Date	ID	Lot#	Batch	P/M characteristics	Raw Function	Raw name	Value_enter	P-item	Properties	Prop. comment
126	2/1	MO968-L49	L49_001	2000		Ad pro.	A	1.00			
127	2/1	MO968-L49	L49_001	2000		Filler		40.00			
128	2/1	MO968-L49	L49_001	2000		Filler		10.00			
129	2/1	MO968-L49	L49_001	2000		Filler		3.00			
130	2/1	MO968-L49		2000		resin	E	20.50			
131	2/1	MO968-L49		2000		Filler	F	0.50			
132	2/1	MO968-L49		2000		resin	G	14.30			
133	2/1	MO968-L49	L49_001	2000		Additive	H	2.00			
134	2/1	MO968-L49	L49_001	2000		Additive	I	0.07			
135	2/1	MO968-L49	L49_001	2000		Filler	J	10.10			
136	2/1	MO968-L49	L49_001	2000		Hardener	K	65.00			
137	2/1	MO968-L49	L49_001	2000	OH/ISO ...			4.00			
138	2/1	MO968-L49	L49_001	2000	NCO/OH i...			1.40			
139	2/1	MO968-L49	L49_001	2000	Mixing Te...			25.00			
140	2/1	MO968-L49	L49_001	2000	Mixing Ti...			40.00			
141	2/1	MO968-L49	L49_001	2000	Mixer typ...			2.00			
142	2/1	MO968-L49	L49_001	2000				40.00	1.1	gel time, min	T0
143	2/1	MO968-L49	L49_001	2000				180.00	2.1	Tack Free time,...	T0
144	2/1	MO968-L49	L49_001	2000				55.00	1.1	gel time, min	38, 1w
145	2/1	MO968-L49	L49_001	2000				230.00	2.1	Tack Free time,...	38, 1w
146	2/1	MO968-L49	L49_001	2000				180.00	1.1	gel time, min	38, 2w
147	2/1	MO968-L49	L49_001	2000				230.00	2.1	Tack Free time,...	38, 2w
148	2/1	MO968-L49	L49_001	2000				44800...	3.1	Viscosity, 2rpm	T0
149	2/1	MO968-L49	L49_001	2000				26880...	3.1	Viscosity, 10rpm	T0
150	2/1	MO968-L49	L49_001	2000				22480...	3.1	Viscosity, 20rpm	T0
151	2/1	MO968-L49	L49_001	2000				757.00	5.1	AL adhesion	T0, min
152	2/1	MO968-L49	L49_001	2000				130.00	5.1	PC adhesion	T0, min
153	2/1	MO968-L49	L49_001	2000				1445.00	5.1	AL adhesion	T0, ave
154	2/1	MO968-L49	L49_001	2000				156.00	5.1	PC adhesion	T0, ave
155	2/2	MO968-L50	L50_001	2000		Ad pro.	A	1.00			
156	2/2	MO968-L50	L50_001	2000		Filler	B	39.40			
157	2/2	MO968-L50	L50_001	2000		Filler	C	9.90			
158	2/2	MO968-L50	L50_001	2000		Filler	D	3.00			
159	2/2	MO968-L50	L50_001	2000		resin	E	21.40			
160	2/2	MO968-L50	L50_001	2000		resin	L	4.90			
161	2/2	MO968-L50	L50_001	2000		Filler	F	0.50			
162	2/2	MO968-L50	L50_001	2000		resin	G	8.00			
163	2/2	MO968-L50	L50_001	2000		Additive	H	2.00			
164	2/2	MO968-L50	L50_001	2000		Additive	I	0.07			
165	2/2	MO968-L50	L50_001	2000		Filler	J	10.00			
166	2/2	MO968-L50	L50_001	2000		Hardener	K	65.00			
167	2/2	MO968-L50	L50_001	2000	OH/ISO ...			4.00			

- **Narrow data structure**
  - Formulation Stacking
  - No row matching
- **Analysis in Tabulate platform**
- **Min. disadvantages as seen in Excel**
- **Chemists perform the formulation in Excel and copy formula & results into JMP table**

FORMULATION WORKSHEET - GEN1

CASE 19: DATA ANALYSIS - TABULATE

Data Courtesy of Dr. Yalin Liu

Worksheet_Gen1 - Tabulate - JMP Pro

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

Local Data Filter

Clear | Favorites

135 matching rows

Inverse

ID (79)

MO968-L42	68
MO968-L44	57
MO968-L49	29
MO968-L50	55
MO968-L51	51
MO968-L52	25
MO968-L53	25
MO968-L54	25
MO968-L55	25
MO968-L67	182
MO968-L68	27
MO968-L69	12
MO968-L74	28
MO968-L75	29
MO968-L80	24
MO968-L82	35
MO968-L83	35
MO968-L84	35
MO968-L89	25
MO968-L90	25
MO968-L92	36
MO968-L93	37
MO968-L94	37
MO968-L95	37
MO968-L96	37
MO968-L98	34
MO968-L99	20
MO968-L100	32
MO968-L101	21
MO968-L102	41
MO968-L103	33
MO968-L104	18
MO968-L105	32
MO968-L106	32
MO968-L107	36
MO968-L108	25
MO968-L109	29
MO968-L110	24
MO968-L111	31
MO968-L112	32
MO968-L113	30

Tabulate

ID = MO968-L42, MO968-L102, MO968-L144

			ID			
			MO968-L42	MO968-L102		MO968-L144
			Date	Date		Date
			1/5	4/22	5/9	7/6
			Batch	Batch	Batch	Batch
			3000	500	600	300
			Lot#	Lot#	Lot#	Lot#
			L42_001	L42_002	L102_001	L102_002	L144_001
Raw Function	Raw name		Sum	Sum	Sum	Sum	Sum
resin	E		20.50	.	0.00	.	.
	G		14.30	.	4.50	.	22.40
	L		.	.	1.50	.	2.00
	Polyol1		.	.	.	.	27.00
	Polyol3		.	.	35.50	.	.
Filler	F		0.50	.	0.50	.	1.00
	B		40.00	.	32.91	.	38.01
	C		10.00	.	10.00	.	.
	D		3.00	.	3.50	.	2.00
	FR_L7		.	.	.	.	5.00
	J		10.64	.	10.00	.	.
Additive	BYK9		.	.	.	.	1.00
	H		.	.	0.50	.	0.50
	I		0.06	.	0.09	.	0.09
Hardener	F		.	.	.	.	2.00
	C		.	.	.	.	20.16
	ISO2		.	.	50.00	.	.
	ISO3		.	.	.	.	38.76
	ISO4		.	.	.	.	38.76
	K		65.00	.	.	.	.
Ad pro.	A		1.00	.	1.00	.	1.00
P/M characteristics							
Mixing Temp			25.00	60.00	25.00	25.00	25.00
Mixing Time			40.00	40.00	5.00	5.00	5.00
OH/ISO mixing v/v			4.00	4.00	4.00	4.00	4.00
NCO/OH index			1.40	1.40	1.40	1.40	1.40
Mixer type (1- Ross, 2-DP, 3-speed)			2.00	2.00	.	.	.
P-item	Properties	Prop. comment					
1.1	gel time, min	T0	24.00	25.00	.	25.00	14.00
		38, 1w	32.00	34.00	.	.	.
		38, 2w	160.00	160.00	.	35.00	.
2.1	Tack Free time, min	T0	120.00	120.00	.	100.00	80.00
		38, 1w	210.00	210.00	.	.	.
		38, 2w	300.00	300.00	.	120.00	.
3.1	Viscosity, 2rpm	T0	30400.00	32800.00	52000.00	.	44000.00
	Viscosity, 10rpm	T0	26080.00	26720.00	28960.00	.	23360.00
	Viscosity, 20rpm	T0	23600.00	24000.00	24400.00	.	18800.00

Batch ID, lot#, size, date, ..

Only display ingredients used in selected formula

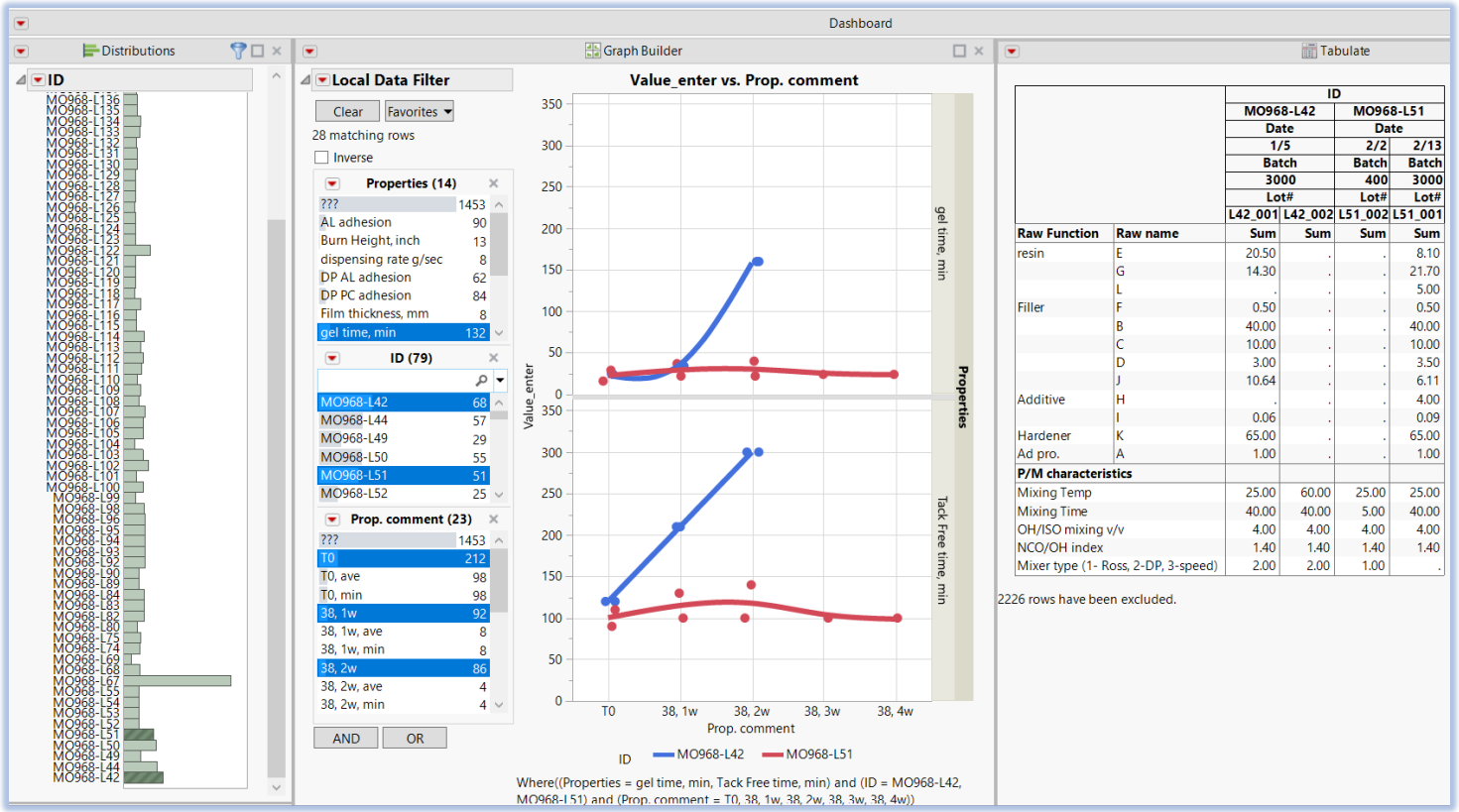
Process & material characteristics

Results & Aging stability

FORMULATION WORKSHEET - GEN1

Data Courtesy of Dr. Yalin Liu

CASE 19: DATA VISUAL & TABULATE ANALYSIS



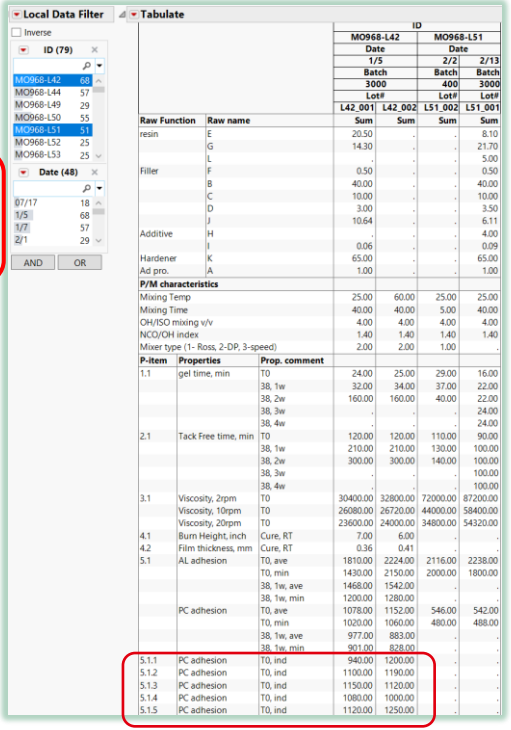
		ID			
		MO968-L42		MO968-L51	
		Date		Date	
		1/5		2/2	2/13
		Batch		Batch	Batch
		3000		400	3000
		Lot#		Lot#	Lot#
		L42_001	L42_002	L51_002	L51_001
Raw Function	Raw name	Sum	Sum	Sum	Sum
resin	E	20.50	.	.	8.10
	G	14.30	.	.	21.70
	L	.	.	.	5.00
Filler	F	0.50	.	.	0.50
	B	40.00	.	.	40.00
	C	10.00	.	.	10.00
	D	3.00	.	.	3.50
	J	10.64	.	.	6.11
Additive	H	.	.	.	4.00
	I	0.06	.	.	0.09
Hardener	K	65.00	.	.	65.00
Ad pro.	A	1.00	.	.	1.00
P/M characteristics					
Mixing Temp		25.00	60.00	25.00	25.00
Mixing Time		40.00	40.00	5.00	40.00
OH/ISO mixing v/v		4.00	4.00	4.00	4.00
NCO/OH index		1.40	1.40	1.40	1.40
Mixer type (1- Ross, 2-DP, 3-speed)		2.00	2.00	1.00	.

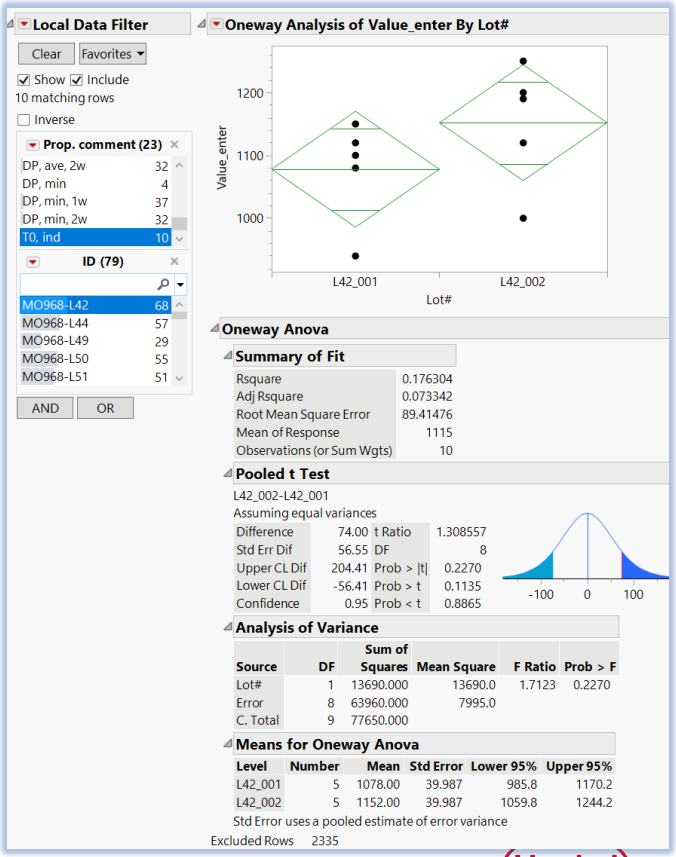
Graph: y (property) vs ID or Prop_comm (NOT ingredient)

FORMULATION WORKSHEET - GEN1

CASE 19: STATISTICAL ANALYSIS

ID	Lot#	Batch	P/M characte...	Raw Function	Raw name	Value_enter	P-item	Properties	Prop. comment
MO968-L42	L42_002	3000				26720....	3.1	Viscosity, 10...	T0
MO968-L42	L42_002	3000				24000....	3.1	Viscosity, 20...	T0
MO968-L42	L42_001	3000				1430.00	5.1	AL adhesion	T0, min
MO968-L42	L42_001	3000				1020.00	5.1	PC adhesion	T0, min
MO968-L42	L42_001	3000				1810.00	5.1	AL adhesion	T0, ave
MO968-L42	L42_001	3000				1078.00	5.1	PC adhesion	T0, ave
MO968-L42	L42_001	3000				940.00	5.1.1	PC adhesion	T0, ind
MO968-L42	L42_001	3000				1100.00	5.1.2	PC adhesion	T0, ind
MO968-L42	L42_001	3000				1150.00	5.1.3	PC adhesion	T0, ind
MO968-L42	L42_001	3000				1080.00	5.1.4	PC adhesion	T0, ind
MO968-L42	L42_001	3000				1120.00	5.1.5	PC adhesion	T0, ind
MO968-L42	L42_001	3000				1200.00	5.1	AL adhesion	38, 1w, min
MO968-L42	L42_001	3000				901.00	5.1	PC adhesion	38, 1w, min
MO968-L42	L42_001	3000				1468.00	5.1	AL adhesion	38, 1w, ave
MO968-L42	L42_001	3000				977.00	5.1	PC adhesion	38, 1w, ave
MO968-L42	L42_002	3000				2150.00	5.1	AL adhesion	T0, min
MO968-L42	L42_002	3000				1060.00	5.1	PC adhesion	T0, min
MO968-L42	L42_002	3000				2224.00	5.1	AL adhesion	T0, ave
MO968-L42	L42_002	3000				1152.00	5.1	PC adhesion	T0, ave
MO968-L42	L42_002	3000				1200.00	5.1.1	PC adhesion	T0, ind
MO968-L42	L42_002	3000				1190.00	5.1.2	PC adhesion	T0, ind
MO968-L42	L42_002	3000				1120.00	5.1.3	PC adhesion	T0, ind
MO968-L42	L42_002	3000				1000.00	5.1.4	PC adhesion	T0, ind
MO968-L42	L42_002	3000				1250.00	5.1.5	PC adhesion	T0, ind
MO968-L42	L42_002	3000				1280.00	5.1	AL adhesion	38, 1w, min



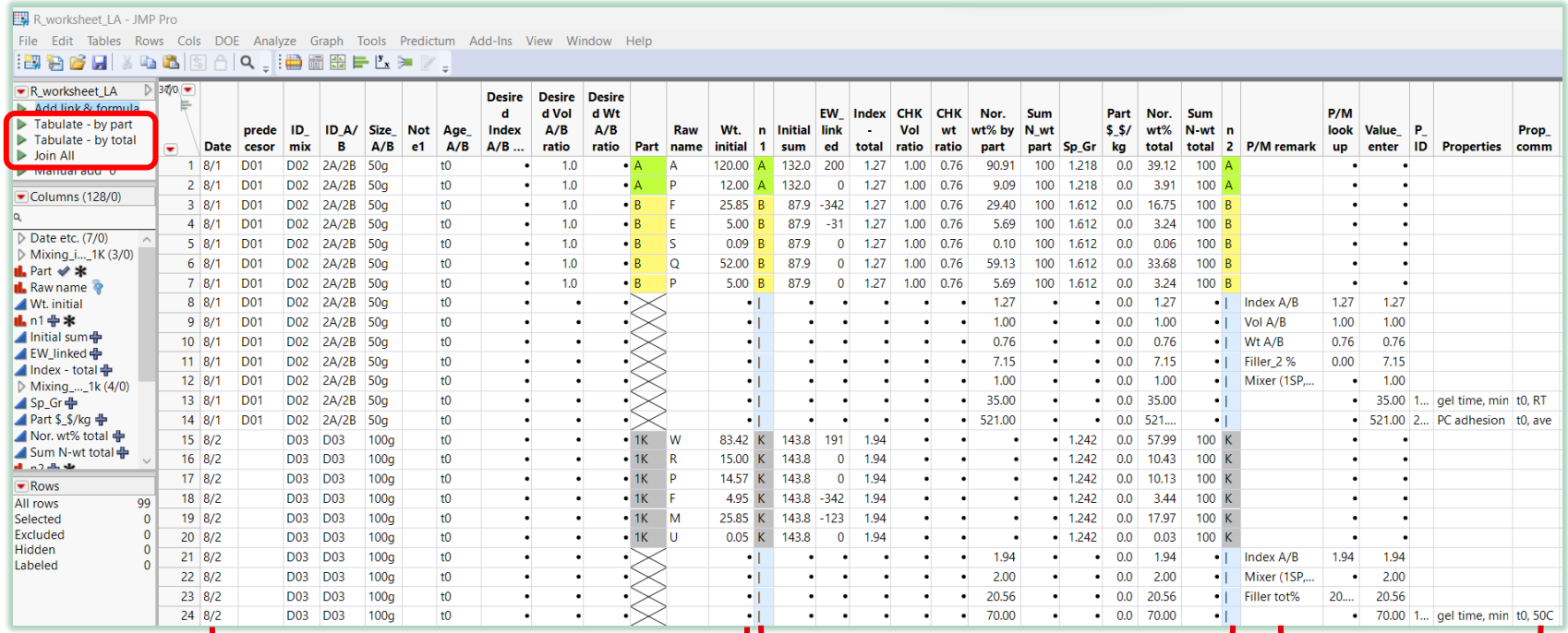


JMP FORMULATION WORKSHEETS

GEN	No. of adhesive component	Formulation calculation	Link to ref. table	Master batch handling	Applicability	Normalization & lookup	Data entry	Output	Implementation
1	1 or 2	None	No	No	1k non reactive, 2k reactive pre-calculated in Excel	No	Narrow format, stacked, no raw matching	tabulate, graphs, wide data format, ML ready	Q1 2022
2	1 or 2	Mixing by volume, by weight, or by stoich.	Yes	No	Reactive & non-reactive	Yes			Q1 2023
3	1	Stoich. Solid content, dry composition	Yes	Yes, multiple parallel or cascading	Solvent borne Reactive & non-reactive	Yes			Q2 2023

FORMULATION WORKSHEET - GEN2

CASE 20: FORMULATION DESIGN AND CALCULATION 1K & 2K



	Date	prede cesor	ID_ mix	ID_A/ B	Size_ A/B	Not e1	Age_ A/B	Desire d Index A/B ...	Desire d Vol A/B ratio	Desire d Wt A/B ratio	Part	Raw name	Wt. initial	n 1	Initial sum	EW_ link ed	Index - total	CHK Vol ratio	CHK wt ratio	Nor. wt% by part	Sum N_wt part	Sp_Gr	Part $_$/ kg	Nor. wt% total	Sum N-wt total	n 2	P/M remark	P/M look up	Value_ enter	P_ ID	Properties	Prop_ comm
1	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	A	A	120.00	A	132.0	200	1.27	1.00	0.76	90.91	100	1.218	0.0	39.12	100	A		•	•			
2	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	A	P	12.00	A	132.0	0	1.27	1.00	0.76	9.09	100	1.218	0.0	3.91	100	A		•	•			
3	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	B	F	25.85	B	87.9	-342	1.27	1.00	0.76	29.40	100	1.612	0.0	16.75	100	B		•	•			
4	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	B	E	5.00	B	87.9	-31	1.27	1.00	0.76	5.69	100	1.612	0.0	3.24	100	B		•	•			
5	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	B	S	0.09	B	87.9	0	1.27	1.00	0.76	0.10	100	1.612	0.0	0.06	100	B		•	•			
6	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	B	Q	52.00	B	87.9	0	1.27	1.00	0.76	59.13	100	1.612	0.0	33.68	100	B		•	•			
7	8/1	D01	D02	2A/2B	50g		t0	•	1.0	•	B	P	5.00	B	87.9	0	1.27	1.00	0.76	5.69	100	1.612	0.0	3.24	100	B		•	•			
8	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	1.27	•	•	0.0	1.27	•	|	Index A/B	1.27	1.27			
9	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	1.00	•	•	0.0	1.00	•	|	Vol A/B	1.00	1.00			
10	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	0.76	•	•	0.0	0.76	•	|	Wt A/B	0.76	0.76			
11	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	7.15	•	•	0.0	7.15	•	|	Filler_2 %	0.00	7.15			
12	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	1.00	•	•	0.0	1.00	•	|	Mixer (1SP,...	•	1.00			
13	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	35.00	•	•	0.0	35.00	1...	gel time, min	t0, RT					
14	8/1	D01	D02	2A/2B	50g		t0	•	•	•			•	|	•	•	•	•	•	521.00	•	•	0.0	521....	2...	PC adhesion	t0, ave					
15	8/2		D03	D03	100g		t0	•	•	•	1K	W	83.42	K	143.8	191	1.94	•	•	•	•	1.242	0.0	57.99	100	K		•	•			
16	8/2		D03	D03	100g		t0	•	•	•	1K	R	15.00	K	143.8	0	1.94	•	•	•	•	1.242	0.0	10.43	100	K		•	•			
17	8/2		D03	D03	100g		t0	•	•	•	1K	P	14.57	K	143.8	0	1.94	•	•	•	•	1.242	0.0	10.13	100	K		•	•			
18	8/2		D03	D03	100g		t0	•	•	•	1K	F	4.95	K	143.8	-342	1.94	•	•	•	•	1.242	0.0	3.44	100	K		•	•			
19	8/2		D03	D03	100g		t0	•	•	•	1K	M	25.85	K	143.8	-123	1.94	•	•	•	•	1.242	0.0	17.97	100	K		•	•			
20	8/2		D03	D03	100g		t0	•	•	•	1K	U	0.05	K	143.8	0	1.94	•	•	•	•	1.242	0.0	0.03	100	K		•	•			
21	8/2		D03	D03	100g		t0	•	•	•			•	|	•	•	•	•	•	1.94	•	•	0.0	1.94	•	|	Index A/B	1.94	1.94			
22	8/2		D03	D03	100g		t0	•	•	•			•	|	•	•	•	•	•	2.00	•	•	0.0	2.00	•	|	Mixer (1SP,...	•	2.00			
23	8/2		D03	D03	100g		t0	•	•	•			•	|	•	•	•	•	•	20.56	•	•	0.0	20.56	•	|	Filler tot%	20....	20.56			
24	8/2		D03	D03	100g		t0	•	•	•			•	|	•	•	•	•	•	70.00	•	•	0.0	70.00	•	|		•	70.00	1...	gel time, min	t0, 50C

Data Entry: heading & formulation input

Calculation Output

Data Entry: P/M & Results

- **Initial formulation does not need to total to 100%.**
- **Mixed formulation is normalized to 100% for easy data analysis.**
- **P/M lookup capable of extract information of columns, raw function, raw %, raw ratio, ...**

FORMULATION WORKSHEET - GEN2

CASE 20: DATA ANALYSIS - TABULATE

Normalized By Total

Tabulate

			Nor. wt% total						
			ID_mix						
			D02	D03	D04	D05	D06	D07	D08
			2A/2B	D03	3A/2B	4A/2B	5A/2B	6A/2B	7A/2B
Raw function[Raw name]		Raw name	Sum	Sum	Sum	Sum	Sum	Sum	Sum
Resin		E	3.24	.	3.22	3.23	3.23	3.24	3.24
		F	16.75	3.44	16.66	16.70	16.71	16.73	16.74
		M	.	17.97	.	.	.	.	.
Hardener		A	39.12	.	.	.	.	.	.
		B	.	.	38.69	26.99	23.11	19.24	15.37
		D	.	.	0.00	11.57	15.41	19.24	23.06
Block_Hardener		W	.	57.99	.	.	.	.	.
Filler		P	7.15	10.13	7.86	7.86	7.86	7.85	7.85
		Q	33.68	.	33.51	33.59	33.62	33.65	33.68
		R	.	10.43	.	.	.	.	.
Additive		S	0.06	.	0.06	0.06	0.06	0.06	0.06
		U	.	0.03	.	.	.	.	.
P/M remark									
Index A/B			1.27	1.94	1.29	1.29	1.29	1.29	1.29
Vol A/B			1.00	.	1.00	1.00	1.00	1.00	1.00
Wt A/B			0.76	.	0.76	0.76	0.76	0.76	0.76
Filler tot%			.	20.56	41.37	41.39	41.40	41.41	41.43
Filler_2 %			7.15	.	.	.	.	.	.
Mixer(1SP,2DP,3RS)			1.00	2.00	1.00	1.00	1.00	1.00	1.00
P_ID	Properties	Prop_comm							
1.1	gel time, min	t0, RT	35.00	.	38.00	40.00	41.50	40.50	43.00
1.2	gel time, min	t0, 50C	.	70.00	.	.	.	.	.
2.1	PC adhesion	t0, ave	521.00	.	715.00	715.00	820.00	825.00	750.00

Normalized By Part

Tabulate

Not (Part = 1K)

			Nor. wt% by part						
			ID_mix						
			D02	D03	D04	D05	D06	D07	D08
			2A/2B	D03	3A/2B	4A/2B	5A/2B	6A/2B	7A/2B
Part	Raw function[Raw name]	Raw name	Sum	Sum	Sum	Sum	Sum	Sum	Sum
A	Hardener	A	90.91	.	.	.	.	.	.
		B	.	.	89.29	62.50	53.57	44.64	35.71
		D	.	.	0.00	26.79	35.71	44.64	53.57
	Filler	P	9.09	.	10.71	10.71	10.71	10.71	10.71
B	Resin	E	5.69	.	5.69	5.69	5.69	5.69	5.69
		F	29.40	.	29.40	29.40	29.40	29.40	29.40
	Filler	P	5.69	.	5.69	5.69	5.69	5.69	5.69
		Q	59.13	.	59.13	59.13	59.13	59.13	59.13
	Additive	S	0.10	.	0.10	0.10	0.10	0.10	0.10
P/M remark									
Index A/B			1.27	1.94	1.29	1.29	1.29	1.29	1.29
Vol A/B			1.00	.	1.00	1.00	1.00	1.00	1.00
Wt A/B			0.76	.	0.76	0.76	0.76	0.76	0.76
Filler tot%			.	20.56	41.37	41.39	41.40	41.41	41.43
Filler_2 %			7.15	.	.	.	.	.	.
Mixer(1SP,2DP,3RS)			1.00	2.00	1.00	1.00	1.00	1.00	1.00
P_ID	Properties	Prop_comm							
1.1	gel time, min	t0, RT	35.00	.	38.00	40.00	41.50	40.50	43.00
1.2	gel time, min	t0, 50C	.	70.00	.	.	.	.	.
2.1	PC adhesion	t0, ave	521.00	.	715.00	715.00	820.00	825.00	750.00

6 rows have been excluded.

FORMULATION WORKSHEET - GEN2

CASE 20: TABLE FORMAT CHANGE TO WIDE FORMAT & GRAPH ANALYSIS

Join ALL_LA - JMP Pro

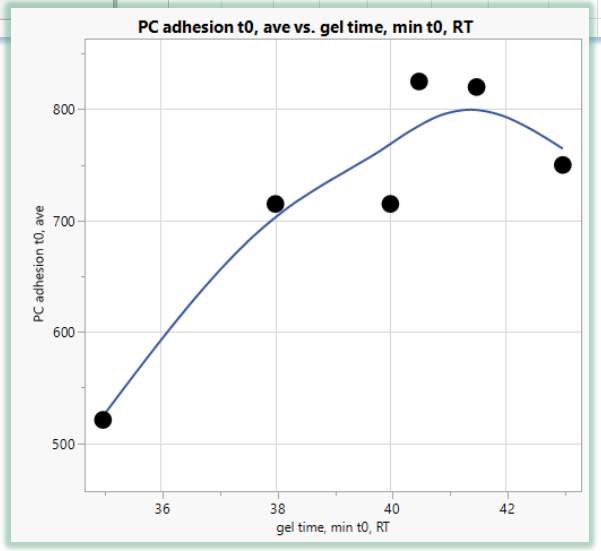
File Edit Tables Rows Cols DOE Analyze Graph Tools Predictum Add-Ins View Window Help

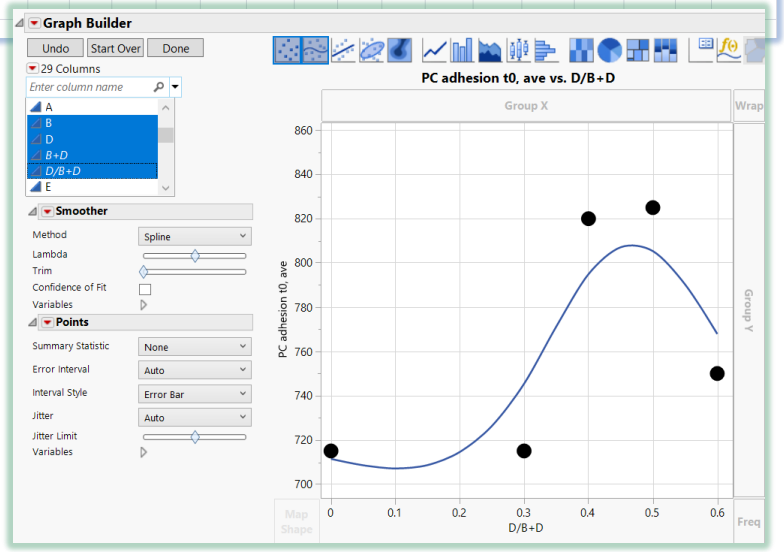
Join ALL_LA
- Source
- Add link & formula
- Tabulate - by part
- Tabulate - by total
- Join All

Columns (27/0)
- Date etc. (4/0)
- Missing(Pro...rop_comm)
- gel time, min t0, 50C
- gel time, min t0, RT
- PC adhesion t0, ave

Rows
All rows

	ID_mix	ID_A/B	Size_A/B	Age_A/B	gel time, min t0, 50C	gel time, min t0, RT	PC adhesion t0, ave	A	B	D	E	F	M	P	Q	R	S	U	W	Index A/B	Vol A/B	Wt A/B	Filler tot%	Filler_2 %	Mixer (1SP,2DP,3RS)
1	D02	2A/2B	50g	t0	•	35.00	521.00	39.12	0.00	0.00	3.24	16.75	0.00	7.15	33.68	0.00	0.06	0.00	0.00	1.27	1.00	0.76	•	7.15	1.00
2	D03	D03	100g	t0	70.00	•	•	0.00	0.00	0.00	0.00	3.44	17.97	10.13	0.00	10.43	0.00	0.03	57.99	1.94	•	•	20.56	•	2.00
3	D04	3A/2B	150g	t0	•	38.00	715.00	0.00	38.69	0.00	3.22	16.66	0.00	7.86	33.51	0.00	0.06	0.00	0.00	1.29	1.00	0.76	41.37	•	1.00
4	D05	4A/2B	150g	t0	•	40.00	715.00	0.00	26.99	11.57	3.23	16.70	0.00	7.86	33.59	0.00	0.06	0.00	0.00	1.29	1.00	0.76	41.39	•	1.00
5	D06	5A/2B	150g	t0	•	41.50	820.00	0.00	23.11	15.41	3.23	16.71	0.00	7.86	33.62	0.00	0.06	0.00	0.00	1.29	1.00	0.76	41.40	•	1.00
6	D07	6A/2B	150g	t0	•	40.50	825.00	0.00	19.24	19.24	3.24	16.73	0.00	7.85	33.65	0.00	0.06	0.00	0.00	1.29	1.00	0.76	41.41	•	1.00
7	D08	7A/2B	150g	t0	•	43.00	750.00	0.00	15.37	23.06	3.24	16.74	0.00	7.85	33.68	0.00	0.06	0.00	0.00	1.29	1.00	0.76	41.43	•	1.00





INTEGRATED WORKSHEET PLATFORM

Worksheet (Stacked / Narrow)

Design, Calculation, Record, Analysis,...

JSL

Tabulate

Graphs:
y vs ID

t & ANOVA
analysis

Virtual link

Raw data
file (Ref)

JSL

Testing data file w replicates

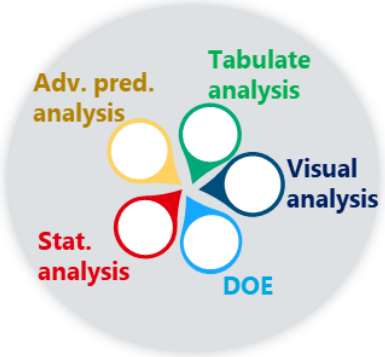
(Unstacked / Wide format)

Machine learning modeling

Graphs: y vs ingredients

Summary

- JMP is NOT just an advanced DOE software!
- JMP data analytics have been effectively utilized in product development at various stages to speed up innovation processes.
- JMP-based formulation worksheet is an integrated platform that features broad formulating capability, all in one, easy operation, ML ready, and more…



Acknowledgements

- AMI & Rocky Hill colleagues in providing data/case for training and presentation

- Henkel AMI management in supporting and driving JMP initiative

Thank you!