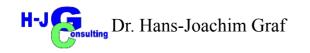


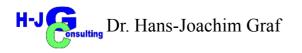


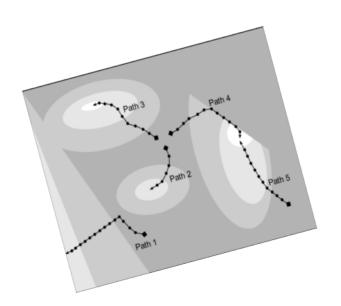
# Bridging AI and DoE





- Content
  - Introduction
  - Development Tools
    - Design of Experiments
    - Artificial Intelligence
  - Datastructure
    - Data Cloud
    - Data Quality
    - Managing Data
  - Conclusion









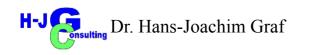
## **Development Tools**

## DoE – New Materials / Processes

 Model / Ingredient Selection & Limits / *Perform Experiments* / Select Result / Confirmation Experiment

## ◆ AI – Historic Compound / Process Data

Data / Criteria / *Prediction* / Select Result / Confirmation Experiment





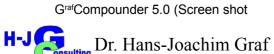
Prediction based on Al

neut data:										Criteria						Output	
per cara.				60AL511	50AL512	50AL513	50AL514	60AL515	50AL518	Name	Min N	ax F	ipen 1	Ca h	Neight Troloff	Colpor.	
Demo Data					0046016	00962010				name					negre moor		
Code:	Cost:	Density:	Ingredients:	Recipes: 50AL511	50AL512	50AL513	50AL514	50AL515	50AL510							Mature 1	
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5003	115.00	1.80	N330	10.00	30.00	50.00	25.00	45.00	75.0	N330	40	75				40.5	
2010	24.00	2.71	CaCO3	20.00	20.00	20.00	20.00	20.00	20.0		10	20				6.45	
002	116.00	0.89	Naphtenic Oil	5.00		45.00	5.00	25.00	45.0			45				8.9875	
5001	385.00	5.60	ZnO	5.00			5.00	5.00	50			-				0.00/0	
001	165.00	0.92	Stearic Acid	2.00			2.00	2.00	20		-	-					
3001	924.00	1.15	PPD	2.00			2.00	2.00				2				2	
1001	158.00	1.15	S	1.50			1.50	1.50		S	0.25	1.5				0.663125	
4001	158.00	1.80	TMTD - 80	1.56	1.90	1.50	1.90	1.50		S TMID - 80	0.25	1.5				0.6775	
K005	708.00	1.28	C88-80	0.65	0.65	0.65	0.65	0.65		C8S - 80	0.65	21				1.632375	
0005	108.00	1.28	000-00	0.66	0.65	0.65	0.65	0.65	0.0	LB3-00	0.65	21	_	_		1.6323/5	
Code:			Properties:														
PR001			Mooney/ML(1+4) 100°C	32.00	36.00	31.00	34.00	30.00	42.0	MooneyML(1+4)	30	60				40.4125	
9R002			Mooney I5 / 120°C	28.00	28.00		28.00	32.00	22.0		30	32				15,8625	
PR002			Density (giccm)	1.06	1.12		1.13	1.16	11	Density (glocm)	1.08	1.2				1 110325	
PR004				42.00	41.00		48.00	48.00	52.0				55	55		55.0075	
PR004			Hardness (*SIA) M300 (Mpa)	42.00	3.00		48.00	46.00	52.0		40	67	22	55		7.475	
PR008			TS Mpal	25.00	21.00	15.00	25.00	20.00	15.3		1.0	25	20			23.355	
PR008			EB (%)	785.00		690.00	716.00	705.00	615.0		540	786	00	600		599.3376	
PR010			C-Set -28°C /24h [%]	22.00	28.00	30.00	17.00	19.00	35.0		17	17		999		59,9625	
PR011			C-Set 0*C (24h [%]	10.00	14.00		8.00	12.00	16.0			16		15		14.405	
PR012			C-Set 23*C /72h [%]	8.00		14.00	9.00	13.00		C-Set 23*C /72b		18		15		15.005	
PR012			C-Set 70°C /24h [%]	39.00		61.00	44.00	50.00		C-Set 70°C /240	17	61		25		24.825	
			o out to o tent inf														
•										-1						-	
Total ingredients				545.15			161.15	201.15		Total ingredients	146.15					167.9005	
Density (calc.)				1.096		1.128	1.137	1.147	1.17	Density (calc.)	1.096					1.114	
Cost (per vol)				262.547	237.377	220 712	259.187	235.816	219.72	Cost (per vol)	219 724 2					261.978	
Cost (per mass)				239.55	212.894	195.667	227.957	205.594	187.63	Cost (per mass)	187.635 2	39.55				235.109	
ecipe ratios in %	<i>u</i>															Rom of covine a	atios (should be 100%).
supervision in a	*.			21,75	2	0.5										100	Anna Laurenne De 100%).

#### • Prediction based on DoE

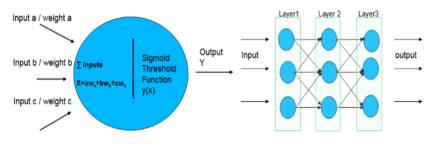
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- 2 R24x-5	et 24/100 /180 (Analyzed) et 24/125 180 (Analyzed) et 72/90 /180 (Analyzed) /180 HL70/150 (Analyzed)	Factor	s							Defeuit Jump to run:	Sho Run #
<ul> <li>R27E v</li> <li>R28 Te</li> <li>R29M3</li> <li>R30TB</li> <li>R31EB</li> <li>R32H v</li> <li>R32H v</li> <li>R32E v</li> <li>R34 Te</li> <li>R35M3</li> <li>R35TB</li> </ul>	289 HL70530 (Analyzers) 289 HL70530 (Analyzers) 209 HL705150 (Analyzers) 279 HL705150 (Analyzers) 279 HL705150 (Analyzers) 2780 HL705150 (Analyzers) 289 HL1001280 (Analyzers) 280 HL1001280 (Analyzers) 280 HL1001280 (Analyzers) 2180 HL1001280 (An	A	MBT5-80 1 ZDT/s 4	vel Low Lew 100 1.000 30 0.600 100 2.0	0 3.00	5td. Dev. 0.0000 0.0000 0.0000	Actual			AS-80 EMETS-80 C2DT/S Fector volue:	
at Productor To			Prediction						Ĩ		
alpha	0.05	Two-side	d Confidence	e = 95% P	opulation = 99	96					
Tolerance Pro	Two-sided		Response	Predict Mean		Observe	d Std Dev	SE Mean	95% for		
Interval			t10/1	50 2.17	361 2.1736	1	0.231059	0.0623642			
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Point Prediction Tool in Design Expert®12 Software (Screen shot)





#### Data Calculation Al



Artificial Intelligence: Neuronal Network and Algorithm

Extended model of an artificial neuron with moderated input weights

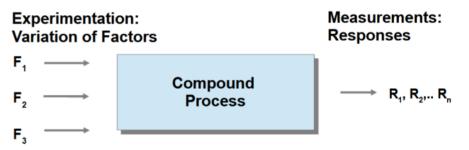
A model with multiple layers of neurons, each connected to the preceding and succeeding layer. • Weights could be assigned to the

connections between nodes

#### Source: T. Rashid, Neuronal Nets, 2017



### Data Calculation DoE



Objective of the Experiment is the identification of the factors  $(F_1, ..., F_n)$  type of influence on the responses  $(R_1, ..., R_n)$  and description with mathematical equations for further processing. ANOVA is used for statistical evaluation.

 $R_{i(1...n)} = f(A_0 + A_1F_1 + ....A_nF_n + ....)$ 



#### Algorithm Al

Matrix multiplication with the terminology of neuronal nets (w - weight, I = Input, o - X-Matrix multiplied sigmoid function)

 $\begin{bmatrix} w1,2 & w2,1 \\ w1,2 & w2,2 \end{bmatrix} = \begin{bmatrix} I1*w1,1 & I2*w2,1 \\ I2*w1,2 & I2*w2,2 \end{bmatrix}$ 

The input values for the subsequent layer is in each case: X = w \* I

Each x must be treated with the sigmoid, respective activation function:

Y =

Values for subsequent layers change to:

**O** = sigmoid (**X**)

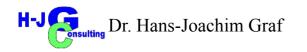
### Algorithm DoE

#### The Prediction is calculated with the

- Intercepts and
- Regression Factors:

(Table shows case for linear regression)

Response	Intercept	F1	F2	Fn
R1	A <sub>1</sub>	A <sub>F1.1</sub>	A <sub>F2.1</sub>	A <sub>Fn.1</sub>
R2	A <sub>2</sub>	A <sub>F1.2</sub>	$X_{\rm F2.2}$	$A_{Fn.2}$
Rn	A <sub>n</sub>	A <sub>F.n</sub>	$A_{Fn.n}$	$A_{Fn.n}$

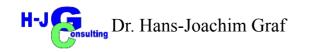




#### **Mathematic basics of Development Tools**

◆ DoE

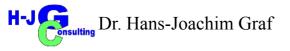
- Linear and 2<sup>nd</sup>, 3<sup>rd</sup> order regression: *Experimental effort*.
- ♦ Al
  - Feed Forward
    - Depending on data accuracy: Experimental effort
  - Machine Learning
    - Limited resources, time constraints a hint for machine learning models Dependency on property





### Data Structure Rubber Compounds

- Ingredients
  - Normalized to 100 parts polymer = phr
- Properties
  - Rheological properties
  - Physicals
    - Other
      - Appearance
      - Dynamics



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K. Los Depart Hose     solve     solve     decould to No.     dec	4 1111 Å 3 65 3 6,00 1 12 3 65 4 65 4 65 4 65 7 75 7 75 7 75 2 45 4 65 4 65 4 65 4 65 4 65 4 65 4 65 4	111 F 178 118 F 118 F			104144100 01 2,00 0,00 0,00 0,00 0,00 0,00 0,00 0,	1 Unite pr 1 Unite pr 1 12 1 22 1 2 1	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	
K. Los Depart Hose     a face     devices VM     devices VM     devices VM     devices     de	4 1111 Å C 85 95,00 95,00 7 75 7 55 7 75 7 75 7 75 7 75 7 75 7	111 F 128 7 Jpc 1 Jpc 2 J 2 J 2 J 2 J 2 J 2 J 2 J 2 J 2 J 2 J	1000000 0000 0 0 00 0,		1104134120 01 2,00 0,00 0,00 0,00 0,00 0,00 0,00 0,	1 Units age 7 U. 2 9 0 02 1,55 4,55 4,55 4,55 4,55 4,55 5,55 4,55 4,55 5,55 4,55 5,55 4,55 5,55 4,55 5,55 4,55 5,555 5,55	07 opt 5.65 7.45 7.45 7.145 0.24 0.24 0.24 0.24 1.45 0.24 0.24 0.24 0.24 0.24 0.24 0.24 0.24	
K. Los Depart Not a factor decurst V0 decurst V0 decu	4 1111 Å 3 65 3 6,00 1 12 3 65 4 65 4 65 4 65 7 75 7 75 7 75 2 45 4 65 4 65 4 65 4 65 4 65 4 65 4 65 4	111 F 178 118 F 118 F			104144100 01 2,00 0,00 0,00 0,00 0,00 0,00 0,00 0,	1 Usters 1 Usters 1 Usters 1 Usters 1 Ust 1 Us	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	
K. Lot Depart Hop a face description descrindescription description description description	4 1111 Å 4 1111 Å 4 1111 Å 4 1111 Å 4 111 Å 4 1111 Å 4	111 F 128 7,00 110 110 110 110 110 110 110 110 110	1000000 000000000000000000000000000000		104144100 01 2,00 0,00 0,00 0,00 0,00 0,00 0,00 0,	1 Usters 1 Usters 1 Usters 1 Usters 1 Ust 1 Us	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	100 C + 4 A 2 M 100 100 100 100 100 100 100 10
K. Los Depart Hose     a face     devices VM     devices VM     devices VM     devices VM     devices     de	4 1111 A C D2 54,00 54,00 54,00 7,00 7,00 7,00 7,00 7,00 7,00 7,00	111 F 1.8, 1 1.8, 1 2,755 1,057 2,2 2,4 2,4 2,4 2,4 2,4 2,4 2,4	2008/00 0x100 4,70 2,00 2,00 1,00 2,00 1,00 0,00 0,00 0,00 0,00 0,00 0,00 1,00 0,0		10000000000000000000000000000000000000	1 Use a get 1 Use	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	1:50 1:50 L:50 L:50 L:50 L:50 L:50 L:50 L:50 L
K. Lot Depart Hose     As Lot Depart Hos	4 1111 Å 4 1111 Å 4 1111 Å 4 1111 Å 4 111 Å 4 1111 Å 4	111 F 128 7,00 110 110 110 110 110 110 110 110 110	1000000 000000000000000000000000000000		104144100 01 2,00 0,00 0,00 0,00 0,00 0,00 0,00 0,	1 Usters 1 Usters 1 Usters 1 Usters 1 Ust 1 Us	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	100 C + 4 A 2 M 100 100 100 100 100 100 100 10
K. Lot Depart Not	4 1111 A C D2 54,00 54,00 54,00 7,00 7,00 7,00 7,00 7,00 7,00 7,00	111 F 1.8, 1 1.8, 1 2,755 1,057 2,2 2,4 2,4 2,4 2,4 2,4 2,4 2,4	2008/00 0x100 4,70 2,00 2,00 1,00 2,00 1,00 0,00 0,00 0,00 0,00 0,00 0,00 1,00 0,0		10000000000000000000000000000000000000	1 Use a get 1 Use	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	1,50 1,50 1,50 1,50 1,50 1,50 1,50 1,50
A. Los Departs Hose     and an     and	4 1191 Å 2 65 95,00 1 10 2 65 4 55 4 55 7 75 7 75 7 75 7 75 7 75 7 7	111 F 138 7 ff 110 22 23 110 22 24 110 22 24 25 25 25 25 25 25 25 25 25 25 25 25 25	100000 0x10 - 0 0x -	1,50 1,50 PDE 0,54 1,50 1,50 1	11.00 1.00	1. Udria est 1. 1. 22 1. 52 1. 52	07 opt 5.05 7.45 7.45 7.45 7.45 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 8.53 8.53 8.53 8.53 8.53 8.53 8.53 8	1:00 1:00
K. Los Departs Hose     since	4 1111 A C D2 54,00 54,00 54,00 7,00 7,00 7,00 7,00 7,00 7,00 7,00	111 F 1.8, 1 1.8, 1 2,755 1,057 2,2 2,4 2,4 2,4 2,4 2,4 2,4 2,4	2008/00 0x100 4,70 2,00 2,00 1,00 2,00 1,00 0,00 0,00 0,00 0,00 0,00 0,00 1,00 0,0		10000000000000000000000000000000000000	1 Use a get 1 Use	07 opt 5.05 7.45 7.45 7.54 0.54 0.54 0.54 0.54 0.54 0.54 0.54 0	1,50 1,50 1,50 1,50 1,50 1,50 1,50 1,50
K. Lot Depart Hose     a face     a face     devices to M     devices to M     devices to M     devices to M     devices	4 1191 Å 2 65 95,00 1 10 2 65 4 55 4 55 7 75 7 75 7 75 7 75 7 75 7 7	111 F 138 7 ff 110 22 23 110 22 24 110 22 24 25 25 25 25 25 25 25 25 25 25 25 25 25	100000 0x10 - 0 0x -	1,50 1,50 PDE 0,54 1,50 1,50 1	11.00 1.00	1. Udria est 1. 1. 22 1. 52 1. 52	07 opt 5.05 7.45 7.45 7.45 7.45 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 8.53 8.53 8.53 8.53 8.53 8.53 8.53 8	1:00 1:00
Ac Loss Departs Hole     and Second View     and Second View     and Second View     and Second View     and View	4 1191 Å 2 65 95,00 1 10 2 65 4 55 4 55 7 75 7 75 7 75 7 75 7 75 7 7	111 F 138 7 ff 110 22 23 110 22 24 110 22 24 25 25 25 25 25 25 25 25 25 25 25 25 25	100000 0x10 - 0 0x -	1,50 1,50 PDE 0,54 1,50 1,50 1	11.00 1.00	1. Udria est 1. 1. 22 1. 52 1. 52	07 opt 5.05 7.45 7.45 7.45 7.45 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 8.53 8.53 8.53 8.53 8.53 8.53 8.53 8	1:00 1:00
K 200 Depart Hoy of the Control Program Hoy	4 1191 Å 2 65 95,00 1 10 2 65 4 55 4 55 7 75 7 75 7 75 7 75 7 75 7 7	111 F 138 7 ff 110 22 23 110 22 24 110 22 24 25 25 25 25 25 25 25 25 25 25 25 25 25	100000 0x10 - 0 0x -	1,50 1,50 PDE 0,54 1,50 1,50 1	11.00 1.00	1. Udria est 1. 1. 22 1. 52 1. 52	07 opt 5.05 7.45 7.45 7.45 7.45 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 8.53 8.53 8.53 8.53 8.53 8.53 8.53 8	1:00 1:00
K 200 Depart Hoy of the Control Program Hoy	4 1191 Å 2 65 95,00 1 10 2 65 4 55 4 55 7 75 7 75 7 75 7 75 7 75 7 7	111 F 138 7 ff 110 22 23 110 22 24 110 22 24 25 25 25 25 25 25 25 25 25 25 25 25 25	100000 0x10 - 0 0x -	1,50 1,50 PDE 0,54 1,50 1,50 1	11.00 1.00	1. Udria e pr 1. 1. 22 1. 52 1. 52	07 opt 5.05 7.45 7.45 7.45 7.45 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 8.53 8.53 8.53 8.53 8.53 8.53 8.53 8	1:00 1:00
K. Lot Depart Hoy     at an     at an     an     another	4 1191 Å 2 65 95,00 1 10 2 65 4 55 4 55 7 75 7 75 7 75 7 75 7 75 7 7	111 F 138 7 ff 110 22 23 110 22 24 110 22 24 25 25 25 25 25 25 25 25 25 25 25 25 25	100000 0x10 - 0 0x -	1,50 1,50 PDE 0,54 1,50 1,50 1	11.00 1.00	1. Udria e pr 1. 1. 22 1. 52 1. 52	07 opt 5.05 7.45 7.45 7.45 7.45 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 2.34 7.55 8.53 8.53 8.53 8.53 8.53 8.53 8.53 8	1:00 1:00



- Al Data Structure
  - Trial&Error Data Collections
  - OFAT Data Blocks
  - DoE Data blocks
    - Property Data According Customer / Market Specification
    - Data Diversity



H-J

- DoE Data Structure
  - Data Sets
    - Blocks of 9 20 Sets

- Property Data Project related
- Data Diversity: blockwise



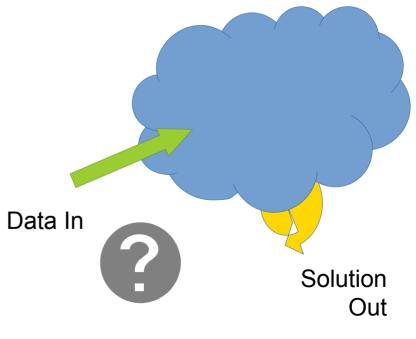
- Data Quality
  - Faulty Data in
  - No useful Solution out
- Sources of Error

H-J

- Lack of Standardization
  - Variation Mixing
  - Variation Testing

Hans-Joachim Graf





Standarization

- Eliminate Redundant Ingredients (Neutralization of Names)
- Separation

H-J

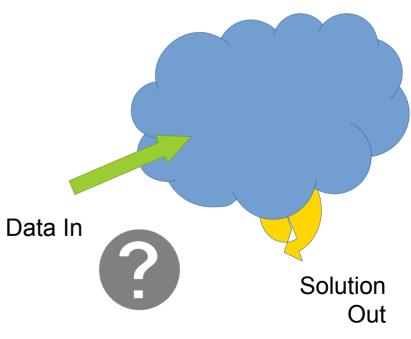
- Polymer Compatibility
- Ingredient Solubility
- Crosslinking Systems

Hans-Joachim Graf



#### Navigating the Complexities of Rubber Development

Data Cloud?



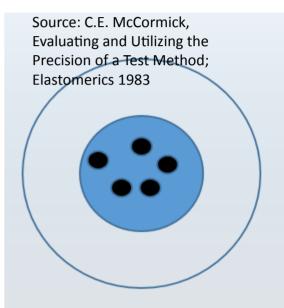




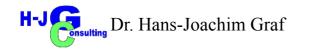
- Decrease of Variation, Increase Precision
  - Laboratory Mixing Machine: Variation
    - Raw Material / Process Protocol Influences
    - Testing

### Test Protocol: 5 instead of 3 samples per Test

- Evaluation of Measurement Error (Man – Machine – Material)
- Design of Experiments: Number of Repeats
- Round Robin Testing with external Laboratories



Good Accuracy Good Precision



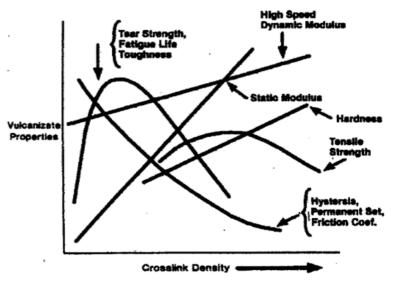


- How to check / improve quality of a historic data pool?
- Al Prediction of compound inside 95% confidence interval
  - Elimination of outliers possible, if ingredient – property relation can be demonstrated
    - Properties correlated to crosslink density (according Coran)
  - Correlation analysis of properties
  - Properties inter-correlated

Hans-Joachim Graf

H-J

# Correlation between crosslink density and physical properties



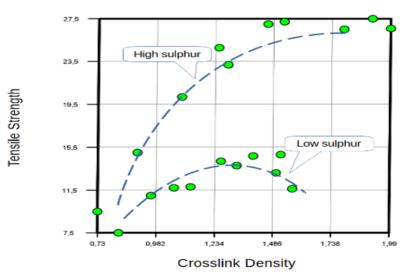
Source: D. Hertz, Elastomerics 1984, A.Y. Coran, in Science Technology of Rubber, § Vulcanization, Academic Press 1994 M.L. Studebaker, RCT 39, 1966

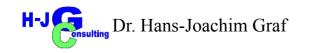
14

#### Navigating the Complexities of Rubber Development

- Properties over Crosslink Density
  - Variation of ingredients cause a shift of properties
    - Hardness / Modulus
    - Static- / Dynamic Force
    - Crosslink Density / CLD
       Concentration

• Variation of Ingredients: Example Sulphur Source: L. Gonzales, et al., KGK 2005







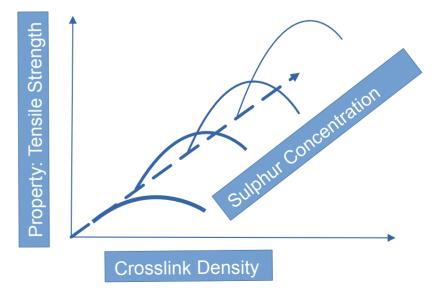


## Checking Data

- Correlation of Related Properties
  - Hardness / Modulus
  - Static- / Dynamic Force
     Crosslink Density / Cross
     Linker Concentration
- Using a consistent sulfur content when cutting out a curve enables the assessment of accuracy by observing the dispersion or clustering of points along the curve.

Coran's Diagram

Variation of Ingredients: Example Sulphur Source: L. Gonzales, et al., KGK 2005



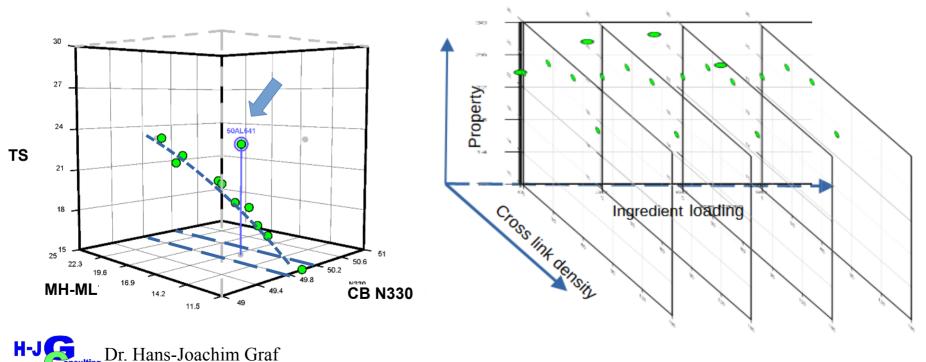
H-J(



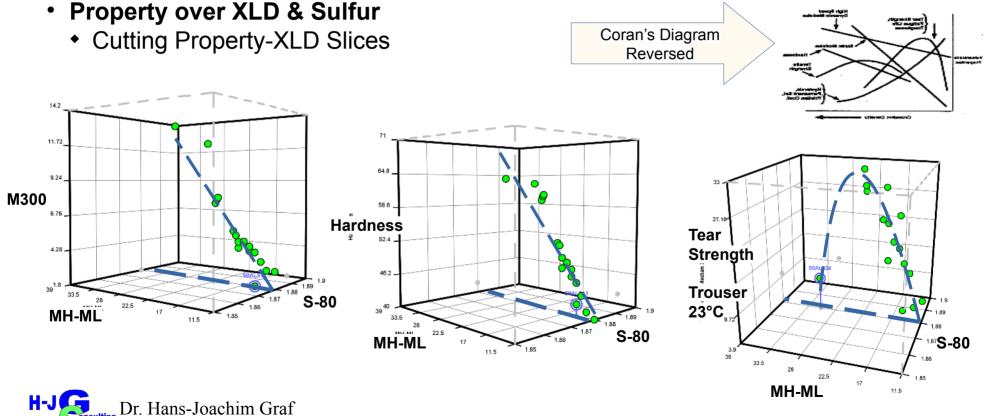
Property Data Slice

With outlier

- Property (TS) over XLD & Loading (CB N330)
  - Cutting property-XLD slices



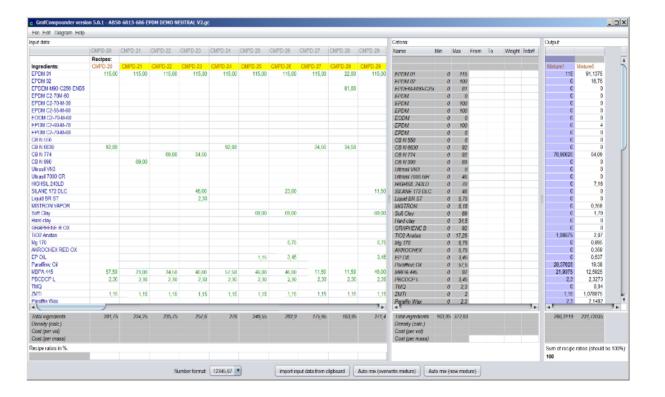






- Data Management
  - Ingredients
    - Copy / Paste ingredients from master ingredient file
  - Neutralization
    - CAS No.
    - Chemical name





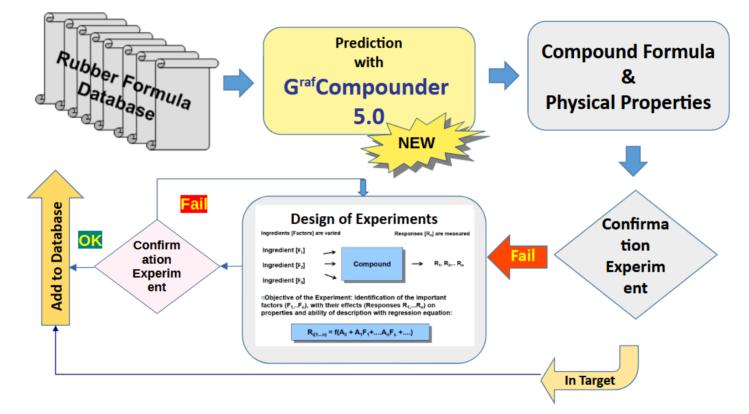


- Data Management
  - Properties
    - Copy / Paste property names from **master property file**
- Standardization Standard properties
- Custom properties.

rt data:												Criteria:						Output:		
MPD-55	CMPD-56	CMPD-57	CMPD-58	CMPD-59	CMPD-60	GMPD-61	CMPD-62	CMPD-63	GMPD-64	CMPD-65	CMPD-66	Name	Min	Мах	From 1	0	Weight Trdoff			
CMPD-55	CMPD-56	CMPD-57	CMPD-58	CMPD-59	CMPD-60	CMPD-61	CMPD-62	CMPD-63	CMPD-64	CMPD-65	CMPD-66									
36.20	36.60	47.50	56.90	28.70	47.70	43.90	44.20	97.50	89.70	92.70	49.9	Mooney Viscosity ML-100 C	17.6	100				30.08975	36.569	
												Mooney Scorch								
23,00	22,10	35,00	35,70	16,90	31,60	27,10	26,10	83,60	71,20	74,80	30,1	ML-125 Cmin	11,5	83,6				20,35175	25,67775	
9,51	11,90	9,55	6,43	8,98	9,25	5,86	5,73	19,18	6,51	44,86	61,6	75-125	4,14	61,64				12,12085	8,87755	
94,05		43,38	15,87	58,98	62,16	13,96	22,28					T35-125 Rhoometer -	5,28	94,05						
0,70	0,70	1,15	1,10	0,49	0.94	0,79	0.76	3,55		3,09	0.9	ML190	0.34	3,55				0,68925	0.88135	
0,46	0,46	0,32	0,35	0,41	0,42	0,41	0,42	0,34	0,34	0,42	0,8	Ts2-190	0,25					0,38265	0,375125	
0,60	0,61	0,55	0,53	0,59	0,60	0,57	0,57	0,57	0,55	0,59	0,9	Tc50-190	0,26	1.03				0,51305	0,536775	
1,28	1,30	1,22	1,15	1,27	1,25	1,17	1,18	1,08	1,07	1,20	2,1	Tc90-190	0,35					1,139775	1,192975	
7,67	7,55	15,26	11,85	9,89	9,30	9,25	8,63	15,10	16,99	10,91	5,2	MH-190	5,11	19,07				7,568075	9,769175	
6,97	6,85	14,11	10,75	9,4	8,38	8,48	7,85	11,55	13,69	7,82	4,3	MH-ML-190 Rheameter -	4,38	17,22				6,978825	8,667825	
0,71	0,75	1,12	1,15	0,51	1,01	0,83	0,83	3,88	3,67	3,38	1,0	ML165	0,32	3,88				0,682975	0,85655	
1,59	1,54	83,0	0,96	1,48	1,39	1,32	1,38	0,63	0,74	1,11	6,1	Ts2-165	0,41	6,14				0,824825	1,0323	
3,27	3,26	3,00	2,87	3,56	3,18	2,96	3,03	2,34	2,62	2,82	6,5	Tc50-165	0,53	6,66				1,63985	2,501325	
7,38	7,38	7,25	7,00	8,23	7,47	7,13	7,35	5,48	6,23	6,87	12,6	Tc80-165	0,9	12,81				3,81435	6,09755	
10,48	10,48	10,23	10,33	11,61	10,68	10,37	10,62	7,96	9,00	9,90	15,6	Tc90-165	1,18	15,87				5,548375	8,8753	
8,47	8,54	17,15	12,18	9,76	9,69	9,44	9,03	16,37	18,20	11,88	5,2	MH-165	5,27	20,43				8,01545	10,1737	
7,76	7,79	16,03	11,03	8,95	8,67	8,61	8,2	12,49	14,53	8,5	4,2	MH-ML-165 Physicals	4,24	18,47				7,332475	9,31715	
51.00	52.00	63.00	66.00		55.90	64.00	54.00	60.00	70.00	54.00	45	Hardness 'ShA	44	66				52.045	65.06	
9.80	11,41	10.13				11.49	18,56	14.65	13,18	19.27	11.0	Tensile (MPai)	3.62	22.35	10	22	100	8.962125	9,98965	
531.69	540.22	167.42	611.92		450.44	649.56	557.43	569.54	763.88	911.32	70	Elongation (%)	135.33	911,32				455,481225	457,594425	
	5,75	4,95		8,19	0,00	1,22	7,49	6,55	6,29	4,34	2,5	Modulus (MPa)	0							
28,61	32,14	31,38	24,37	48,26	0,00	\$1,01	45,32	41,31	38,97	44,48	35,1	Tear (N/mm)	0					27,15255	29,4538	
1,04	1,04	1,08	1,05		1,04	06	1,05	1,06	1,07	1,06	1,042	Density	0,98	1,17				1,042675	1,062825	
												Heat Aging-165								
5,40	16,60	40,80			0,70	-3,30	4,50	-16,30	-13,20	-16,60	13,	ATensile (%)165	-16,6	40,8		0	50	0,32975	0,01	
0,60	6,30				-10,20	-20,30	-15,00	-43,30	-50,80	-53,30	-26,	∆Elongation (%)	-56,9	6,3	-2	0	50	0,0055	-2,00225	
2,00	1,00	3,00			3,00	5,00	5,00	9,00	7,00	10,00	4,	∆Hardness (*	1	10	0	2		2	2,6625	
<u> </u>							(	-				- <b>1</b>					7.6	-		7
251,85	222	223,5	232,5	205	237	237	237	237	237	237	23	Total ingredients	163,95	372,83				266,3119	231,72035	
												Density (calc.) Cost (per vol) Cost (per mass)								
ipe ratios in	%:																	Sum of recipe 100	ratios (should b	ie 10







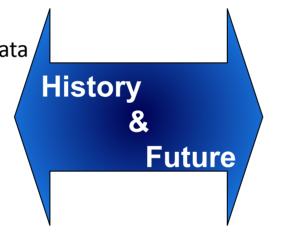




#### Artificial Intelligence: GrafCompounder

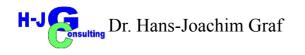
- Compound History
- Analyze / Eliminate Foulty Data
- Simulate
- Select Solution for Confirmation Trial

#### ➢ Confirm



#### **EXPERIMENTAL DESIGN**

- Explore Materials
- Evaluate
- Decide
- Select Possible Solution for Confirmation Trial
- Confirm





# Conclusion

- DoE and AI complement each other perfectly.
- ◆ All Data in the cloud is not recommended.
- ◆ Quality of data remains an issue.
- Database can be improved with suitable tools.
- Management of data will enhance AI accuracy

