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A Discussion of Process Effects on the EX-99 Propellant Characteristics and Extrusion Behavior

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Continuous Mixer and Extruder Users Group Meeting

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Questions and Background

- **Ballistics: Contributions of Process Quality/ Control vs. Inherent Powder Characteristics**
- **How Do Process Conditions Affect Physical Properties Ballistics?**
- **Screening Experiments:**
  - **Process Effects Understood**
  - **Send the Best to Test**
- **Relate Physical Properties Back to the Process**

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Designed Experiments

- Important Method of Investigation for Complex Processes
- Adopted Methods in the Early 90s
- Screening Design
  - Main Effects: Is Temperature Important or Not?
  - Magnitude: Is Temperature More Important Than RPM?
  - No Insight on Interactions
- Power to Make Predictions
- Directions for Optimization

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Conditions

Two-Level Factors

Solvent Content (weight % of wet grain)	**11.5**	**12.5**
Die Temperature (°F)	**90**	**120**
Extruder Screw Speed (rpm)	**80**	**110**

Three-Level Factor: Screw Design

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Experiment Matrix

Identification	Solvent Concentration	Extruder & Die Temp. (°F)	Extruder rpm
Screw Geometry-Screw Design #45			
A	11.5	90	80
B	11.5	120	110
C	12.5	120	80
D	12.5	90	110
Screw Geometry-Screw Design #46			
E	11.5	120	80
F	11.5	90	110
G	12.5	90	80
H	12.5	120	110
Screw Geometry-Screw Design #48			
I	12.5	110	90
J	11.5	80	90
K	12.5	80	120
L	11.5	110	120

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Physical Property: Good Models

Dry Diameter	**Temperature (neg.)** **Solvent (neg.)**
Avg. Diameter of Outer Perforation	**Screw Geometry** **Temperature (neg.)** **RPM (pos.)**
Avg. Diameter of Center Perforation	**Screw Geometry** **Solvent (neg.)**
Inner Web Thickness	**Solvent (neg.)** **Temperature (neg.)** **RPM (pos.)**

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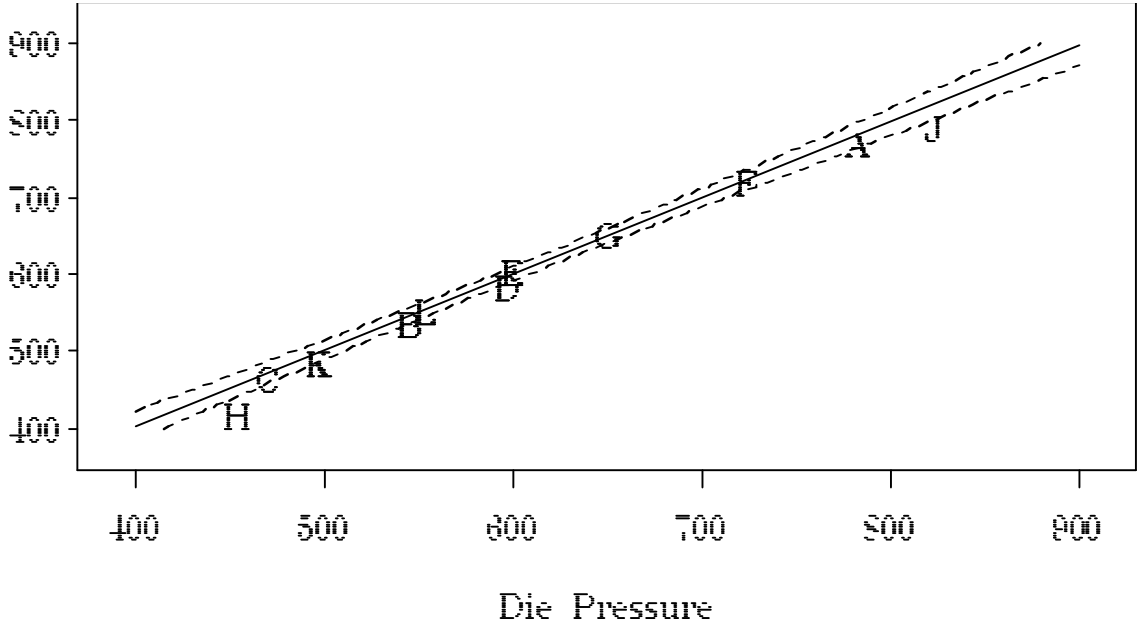
Process Effects: Good Models

Die Pressure	**Temperature (neg.)** **Solvent (neg.)** **RPM (neg.)**
Extruder Torque	**Temperature (neg.)** **RPM (neg.)** **Solvent (neg.)**



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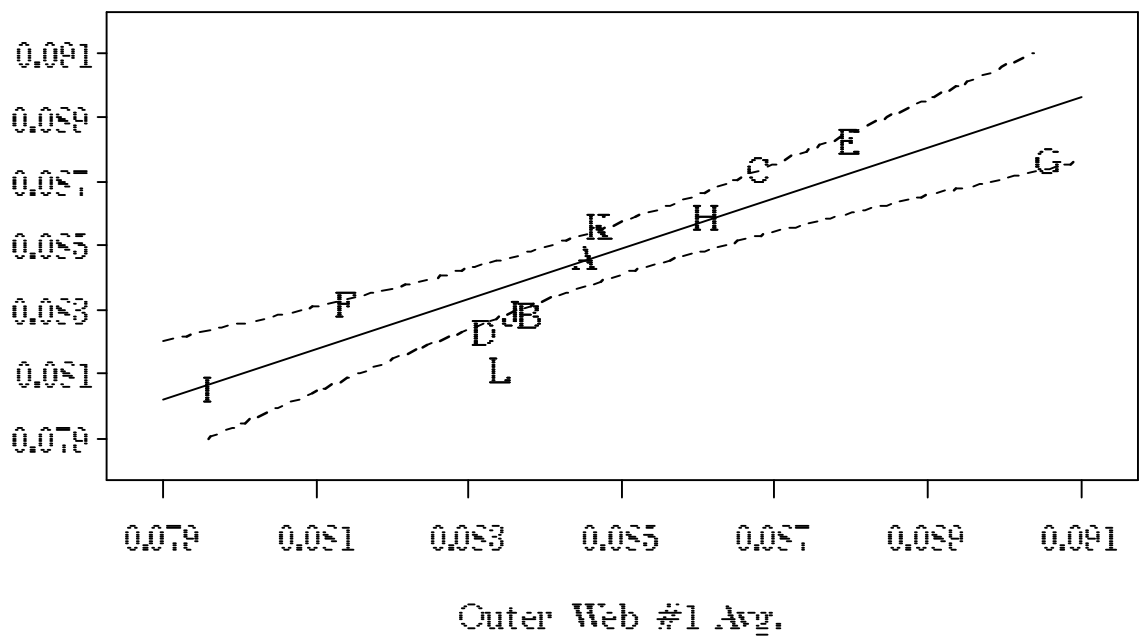
Physical Property: Fair Models

White Patches (binder-rich areas)	**Screw Geometry -Increased Mixing Intensity RPM, Temp., and Solvent**
Outer Web Thickness	**Screw Geometry RPM (neg.)**



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Physical Properties Indifferent to Process Conditions

- Range Too Small (Not Influenced by the Process)
- Influenced by Uncontrolled Source of Variation

- Dry Density was Very Uniform
- Average Grain Length
  - Independent of Process
  - Wholly Dependent Upon On-Line Cutter

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Process Optimization and Condition Selection

Solvent Percentage	Process Temp. (°F)	Extruder RPM	Inner Web – Outer Web	Comment
12.50	120	80	-0.0014	Condition K
12.25	120	80	0.0000	Optimum within design space
12.00	120	80	+0.0014	Take-away considerations
12.00	120	75	+0.0002	Recommended optimum
12.00	110	75	+0.0022	Production conditions

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Prediction Comparison for Two Lots

	Lot #IH940-OOE-EX99-0088	Lot #IH940-OOE-EX99-0089	
Property	**Observed**	**Observed**	**Predicted**
Dry Diameter (in.)	0.4007	0.4017	0.4008
Outer Perf Diameter #1 (in.)	0.0168	0.0168	0.0187
Center Perf Diameter (in.)	0.0171	0.0167	0.0177
Inner Web Thickness (in.)	0.0875	0.0874	0.0876
Outer Web Thickness #1 (in.)	0.0863	0.0865	0.0854
Die Pressure (psig)	605	-	628
Extruder Torque (in.•lbs.)	210	-	

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Conclusions

- **Case Study for Characterizing a Twin Screw Process**
- **Full Testing of All Samples (*Not Just the Pretty Ones*)**
- **Results Were Applied to 700 lb. Test Lot**
- **Power to Predict Results at Untested Conditions**
- **Jointly Solve for Optimization of More Than One Parameter**