WHAT EXACTLY IS "SCIENTIFIC MOLDING"?

Demystifying The Scientific Molding Misconceptions

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Notable Quotes from the Industry

• Scientific injection molding is a highly technical, scientific approach to developing and optimizing an injection molding process

• Scientific molding is best defined as an extension of decoupled molding theory.

• Scientific Molding is a practice for achieving optimal control of the injection molding process to deliver faster molding cycles, higher yields, and a more robust molding process. This optimal control of the molding process is realized by focusing mainly on the behavior of the material in the mold, rather than on the machine.

• Scientific Injection Molding is typically used in the production of complex parts and components where small variations in molding variables can severely impact the process or finished product
Scientific Molding is Not…………..just

- Decoupled molding
- Cavity pressure monitoring or controlling using transducers
- For highly complex and close tolerance parts
- Developing viscosity – shear rate curves
- A new advanced molding technology
- Having a “Master Molder” certified technicians
What is Scientific Molding?

Scientific Molding is the term coined in by John Bozzelli 25 years ago to explain the fact that **The entire molding process is based on Scientific Principles.**

Injection molding started out as science, but due to lack of understanding, comprehension and education it turned into ART.
What is The Scientific Approach To Injection Molding?

• Science of Injection molding
• Everything substantiated by scientific data
• Scientific approach to establishing molding variables
• Understanding of four critical components
  - Material
  - Part Design
  - Tooling
  - Processing

Systematic Troubleshooting
Employee Education

Cultural Shift in Business Philosophy – strong management commitment

• Every decision Must be backed by scientific data
• Never try to solve Material, Design or Tooling issues through Processing
MOLDING IS A SCIENCE
NOT
An ART

Art of molding through Scientific Principles
<table>
<thead>
<tr>
<th>Old Ways</th>
<th>New Ways</th>
</tr>
</thead>
<tbody>
<tr>
<td>How</td>
<td>How &amp; Why</td>
</tr>
<tr>
<td>Art (sight, sound and touch)</td>
<td>Science</td>
</tr>
<tr>
<td>Myth</td>
<td>Facts</td>
</tr>
<tr>
<td>Intuitive</td>
<td>Systematic</td>
</tr>
<tr>
<td>Focus on Molding Only</td>
<td>Wide focus</td>
</tr>
</tbody>
</table>

**Decisions based on DATA and DATA only**
Understanding and Applying Science

### Intensification Ratio

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Intensification Ratio</th>
<th>Hydraulic pressure</th>
<th>Plastic pressure</th>
<th>Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulic</td>
<td>10:1</td>
<td>1000 psi</td>
<td>10,000 psi</td>
<td>A 200T</td>
</tr>
<tr>
<td>Plastic (melt pressure)</td>
<td>15:1</td>
<td>1000 psi</td>
<td>15,000 psi</td>
<td>B 200T</td>
</tr>
</tbody>
</table>

If the area of the ram is 10 sq.in. and area of the non-return valve is 1 sq.in. the ratio is 10:1
Understanding Molding

Materials

Design

Tooling

Process

Optimizing All – Essential for widening the process window
Amorphous Polymers

- Generally clear.
- No specific melting temperature.
- Low shrinkage on freezing.
- Cooling rate has a moderate effect on properties.
- Orientation has a low to moderate effect on properties.
- Low to medium chemical resistance.

ABS, PS, PC, PVC, Acrylic

Semi-Crystalline Polymers

- Generally cloudy to opaque.
- Specific melting temperature.
- High shrinkage on freezing.
- Cooling rate significantly effects properties.
- Orientation has a strong effect on properties (anisotropic).
- Good to high chemical resistance.

Nylon, Polyesters, Acetal
How does part design affect molding?

• Too thick/too thin walls............ Sinks, Voids, Filling issues

• Deep Ribs............. Filling and venting issues

• Thick ribs...............Sink marks

• Sharp corners........Highly stressed parts

• Insufficient Draft.........Part sticking

CANNOT SOLVE DESIGN ISSUES WITH PROCESS TINKERING
How Much Draft?

Although there are exceptions, a draft of $\frac{1}{2}^\circ$ per side is the minimum (your molder will probably ask for at least $1^\circ$), with some situations requiring 1.5 to 3$^\circ$ or more. Obviously, since the more draft you have, the easier it will be to eject.
Understanding Tooling

• Mold Material considerations – High Thermal conductivity alloys
• Runners – balancing – sizing
• Runners control cooling time in small parts........Hot runner technology
• Gates – number and types

• Venting - Understanding Science behind venting
Molding Process

Scientific Approach to Molding cannot be achieved with underperforming Molding machine

Machine must be capable of repeating cycle after cycle

Auxiliary Equipment must be in top working conditions
L/D and Compression Ratio

Compression Ratio

GP Materials    3:1
PVC            1.4:1
Acetal         4:1

\[
\frac{L}{D} = \frac{\text{Flight length of screw}}{\text{Outside diameter of screw}}
\]

Compression Ratio = \frac{\text{Depth of feed section}}{\text{Depth of metering section}} = \frac{D_f}{D_m}

Figure 4C
Barrier, Mixing & specialty Screws

Typical Color Master Geometry:

PVC Screw

Scientific Approach to Injection Molding
Screw Barrel maintenance

Figure 1. Processors should create a form like this one to note important process data, as well as significant part quality anomalies such as burning, streaking or sticking.

Figure 2. Use a flight micrometer or gauge block to measure the flight diameter at every turn. Record these reading every six to twelve months to track the progress of wear on the screw.

Figure 3. A dial bore gauge may be used to measure the barrel ID at five-inch intervals along the length of the barrel. Variance from nominal original dimensions indicates wear.

Source: Glycon Inc.
Check Ring Repeatability Study
A. Set up machine to run standard parts
B. Turn off pack and hold time and pressure
C. Make 10 Fill only shots
D. Weigh the parts and record weight
E. Calculate
Acceptable variation is 5% max.
Molding Process Variables

- Pressures: Injection – Pack – Back
- Temperatures: Barrel – nozzle – mold – Hot Runner
- Time: Injection Forward – Pack & Hold – Cooling
- Flow rate: Injection Speed
- RPM: Screw RPM
- Cushion: Cushion Size
- Clamp: Clamp Tonnage (Clamping Pressure)
- Others: Flow Rate (GPM), Hydraulic oil temperature, ambient Condition

Science Tells us that it is impossible to control any process by focusing on and adjusting too many variables
Major Process Variables

Heat

Pressure

Flow Rate

Cooling
Temperature

What is important… Barrel temperature or Melt temperature?

Optimum MELT TEMPERATURE is the key to successful molding

Factors affecting melt temperature

• Barrel temperature settings
• Screw speed
• Screw back pressure
• Residence time
• Cycle time

Melt temperature affects cycle time

BTU’s (heat) IN = BTU’s (heat) OUT
IN ORDER TO REPRODUCE THE SAME PROCESS ON MULTIPLE MACHINES
MELT TEMPERATURE IS ONE VARIABLE THAT MUST BE CONTROLLED AND DUPLICATED
What is pressure?

Pressure is Resistance to FLOW

Injection Pressure  1\textsuperscript{st}  stage pressure
Packing/Holding Pressure  2\textsuperscript{nd}  stage pressure
Back Pressure

Cavity Pressure  Most Important

Best indicator of what the melt is doing in the mold
Hydraulic vs Plastic Pressure

Area of Non-Return Valve is 1 in²

Area of ram is 10 in²

Intensification Ratio is 10:1

Pump

Injection Molding Solutions  1019 Balfour St  Midland, MI 48640  Ph: 989.832.2424  Fax: 989.832.8743
Email: John@ScientficMolding.com; Web site: www.ScientficMolding.com
Pressure Losses in Injection Molding Process

Flow path:
- Nozzle: 1800
- Sprue & runner: 1259
- Gate: 393
- Part: 11,693
Shear Thinning?

One of the hardest concepts in Plastics: As speed increases, the material gets thinner and easier to push.

Non-Newtonian Behavior of Polymers

Source: RJG

Source: FIMMTECH
Cooling & Water Management

**Basics**

Water pressure differential
25 to 30 psi

Water Temperature differential
< than 4°F

Typical Flow rate
1.5 GPM each line

Reynolds Number > 4000

- Heat Pipes
- High Thermal conductivity Alloys
- Conformal Cooling
Systematic Troubleshooting and problem solving

Factors affecting Quality of Molded parts

- Filling Phase – Surface defects, Jetting, Blush, Gate Fracture, burning, flow marks, Molecular orientation, Knit lines
- Packing Phase – Flash, Some surface details
- Holding Phase – Voids, sinks, warpage, part density
- Cooling Phase – Part dimensions, Warpage

Source: Bayer
Separate Fill from Pack/Hold

- **First Stage**: Fill the mold fast as possible, with abundant pressure.

- Transfer by **screw position** when the cavities are 90-95% full. The ram inertia is used up just before the cavities fill.

- **Second stage**: Hold pressure is used to complete the filling and pack out the parts. Hold until gate seals.

Source: RJG
Why separate Injection from Pack and Hold?

• In conventional molding theory, part of the packing takes place during injection cycle.

• Variations in melt viscosity (created by velocity variations) creates unstable, inconsistent packing and therefore it results in part dimension variations.

• By using injection time simply to fill the mold as fast as possible and relying on Pack and Hold to one can achieve consistent velocity and consistent packing and therefore consistent quality parts.
STEP 1: MOLD FUNCTION QUALIFICATION

(Scientific Processing Section)

START

6 STEP STUDY

1 - VISCOSITY STUDY

2 - CAVITY BALANCE

3 - PRESSURE DROP

4 - PROCESS WINDOW

5 - GATE SEAL STUDY

6 - COOLING STUDY

PART OR MOLD ISSUES

- NOT OK

OK

OK

OK

OK

OK

NOT OK

NOT OK

NOT OK

NOT OK

FIX MOLD OR PART DESIGN

STEP 2: MOLD-PART QUALITY QUALIFICATION

(Design of Experiments Section)

SELECT DOE PARAMETERS

PERFORM DOE

SELECT PROCESS

RUN PROCESS

ADJUST MOLD STEEL

DETERMINE DPW

RUN SHORT PRODUCTION RUN TO EVALUATE THE MOLDING PROCESS AND MOLDING PROCESS CAPABILITY

PLEASE NOTE: THIS FLOW CHART HAS BEEN DEVELOPED BY FIMMTECH AND IS A RECOMMENDED PROCEDURE. THE USERS SHOULD USE THEIR OWN DISCRETION AND JUDGMENT IN FOLLOWING THE PROCEDURE ESPECIALLY KEEPING SAFETY IN MIND. THE USER IS SOLELY RESPONSIBLE FOR ALL CONSEQUENCES.

-SUHAS KULKARNI, WWW.FIMMTECH.COM

RECOMMENDED MOLD QUALIFICATION PROCEDURE
All Inclusive Scientific Molding practices

- Universal set up Card (Only 4 things are needed)
- Moldflow simulation and analysis
- Cavity pressure monitoring and control
- Automation and Lights-out molding
- Molding Essentials
Molding Operation Essentials

- Accurate gram scale (Gate seal study and check ring repeatability study)
- Digital pyrometer
- Stop watch
- Flow meter
- Dew point meter/Moisture Analyzer
- Dial indicator with magnetic base to check mold deflections
- Flash light
- Fold-out Mirror
- Material Process data sheets.
Final Word

• Scientific Molding cannot be implemented from the “Bottom UP”
• Strong Commitment from management essential
• Educate your personnel
• Rome was not built in a day – Scientific Molding will take time
• Imperative to have Strong Foundation
• Accept the new Paradigm – STOP RESISTING THE INEVITABLE CHANGE

• Rely on “SCIENCE”
The course emphasis is on scientific approach to a somewhat complex injection molding process in order to simplify and eliminate basic misunderstanding about processing techniques employed today throughout the industry. Students will learn the importance of understanding polymer basics, material flow properties, viscosity-shear rate curve, and major plastics variables in molding, decoupled molding techniques, data analysis and interpretation.

The course will cover fundamental and scientific approaches to material drying, venting, cooling, use of regrind, how to prepare universal set-up sheet, cycle time optimization, tooling considerations, etc. Use of modern tools and techniques such as mold flow analysis, cavity pressure transducers, and data acquisition tools along with troubleshooting techniques will also be covered.

**Course Content:**
- Polymer Basics, Plastics Materials and Flow Characteristics
- Part Design Fundamentals
- Overview of Basic Injection Molding Process
- Drying, Material Mixing, Coloring, Regrind Usage
- Major Process Variables
- Decoupled Molding, Universal Set Up Sheet
- Tooling Considerations, Venting, Cooling, Ejection
- Cycle Time Optimization and Troubleshooting Techniques
- Mold Flow Analysis
- How to Improve Productivity
- Modern Injection Molding Operation

**Dates:** Saturdays, September 17th and 24th 2016  
**Time:** 8:00 AM to 5:00 PM

**Location:** Cal Poly Pomona, Bronco Student center (Lyra Room)

**Instructor:** Vishu H. Shah, Consultek Consulting Group [www.consulteksa.com](http://www.consulteksa.com)

**Registration by Telephone**  
Students may call the College of the Extended University at [909.869.2288](tel:9098692288) to be placed on the class roster; fees must be paid to guarantee a seat in any class. Students may register by telephone with MASTERCARD or VISA.

**Registration by Internet:** [www.ceu.csupomona.edu](http://www.ceu.csupomona.edu)

For more information, call:  
College of the Extended University  909-869-2288  
Or Instructor: Vishu Shah  909-465-6699
Any Questions?