CONSULTEK LLC

Educational Seminars

Multimedia Tour

www.consultekusa.com

714-674-1981
## Seminars

<table>
<thead>
<tr>
<th>Seminar</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastics A To Z (Theory and Practice)</td>
<td>3</td>
</tr>
<tr>
<td>Residual Stress and photoelastic Analysis</td>
<td>27</td>
</tr>
<tr>
<td>Plastics failure Analysis &amp; Testing</td>
<td>35</td>
</tr>
<tr>
<td>Plastics Identification and Material Selection</td>
<td>49</td>
</tr>
<tr>
<td>Plastics Part design</td>
<td>61</td>
</tr>
<tr>
<td>Tooling For Injection Molding</td>
<td>75</td>
</tr>
<tr>
<td>Scientific Molding</td>
<td>91</td>
</tr>
<tr>
<td>Micro Molding</td>
<td>107</td>
</tr>
<tr>
<td>Energy Efficient Injection Molding Operation</td>
<td>120</td>
</tr>
<tr>
<td>Gas Assist and Microcellular (Mucell®) Technology</td>
<td>131</td>
</tr>
</tbody>
</table>
PLASTICS A TO Z
Workshop for Injection Molders

Vishu Shah
Consultek
Topics

Plastics Industry Overview, History, Growth, Future
Polymer Chemistry Basics
Polymer Structure-Properties-Applications
Modified Plastics-Alloys-Composites
Elastomers
Product Design Basics
Material Selection Process & Interpreting material data sheets
Plastics Identification Techniques
Processing Techniques
Plastics Tooling
Decorating and Printing
Assembling and Secondary Operations
Part Costing
Testing and Failure Analysis
Plastics Industry Standards and Organizations
Recycling
Educations and Seminars
Where to get more information…….
Polymers

Chemical compounds formed when many small chemical units (monomers) combine to form large molecules with a regular repeating structure.
Size of molecules

**Polymers**

Size of the Molecules

**Methane** = $\text{CH}_4 \downarrow \text{Gas}$

**Octane** = $\text{C}_8\text{H}_{18} \downarrow \text{Liquid}$

**Paraffin Wax** = $\text{C}_{50}\text{H}_{102} \downarrow \text{Solid}$

**Polyethylene** = $\text{C}_{2000}\text{H}_{4002} \downarrow \text{Polymer}$
Organization of the Molecules

Solid State Structure of *Thermoplastics*

**Amorphous**

*No polymer structure.*

*Examples:* Polystyrene, Polycarbonate, PMMA

**Semi-Crystalline**

*Contains both crystalline (ordered) and amorphous polymer.*

*Examples:* Polyethylene, Polypropylene, PET, Polyamides (nylon)
ACETAL

Structure

Properties Acetal copolymer provides:
- High tensile strength and stiffness
- Exceptional dynamic fatigue strength and dimensional stability
- High toughness and good resilience
- Minimal moisture absorption
- Low friction and wear properties
- Hard, high gloss surface
- Superior property retention up to 220ºF in air and 180ºF in water
- Excellent resistance to a wide range of chemical, oils, greases and solvents
- Easy to process and fabricate
POLYETHYLENE

Structure

Properties
Excellent dielectric properties, moisture resistance,
chemical resistance, FDA approved, Poor weathering properties,
difficult to bond, easy to process.

Applications
Containers, toys, Bags, film, agriculture parts,
Automotive parts, tubing, bottles, Gas tanks.....
Wire & Cable....
# Liquid Crystal Polymers (LCP)

<table>
<thead>
<tr>
<th>Thermoplastics</th>
<th>Thermosets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amorphous polymer</td>
<td>Thermosetting polymer</td>
</tr>
<tr>
<td>Semi-crystalline polymer</td>
<td>Heating</td>
</tr>
<tr>
<td>Liquid crystalline polymer</td>
<td>Heating</td>
</tr>
<tr>
<td>Heating</td>
<td>Heating</td>
</tr>
<tr>
<td>Cooling</td>
<td>Cooling</td>
</tr>
</tbody>
</table>

## Consequences of Molecular Structure

- **High Flow-Fills Thin, Complicated Parts Easily**
- Rapid Set-up - Fast Cycle Time
- Excellent Dimensional Stability
- High Strength/Stiffness
- Chemical Stability
- Excellent Barrier Properties

## High Flow of LCPs

- **Spiral flow vs. thickness**
- LCPs fill thin parts easily
ELASTOMERS

- Thermoplastic or Thermoset
- Thermoplastic Elastomer (TPEs) combine processing advantage of thermoplastics with properties of cross linked rubber.
- Use standard processing equipment, decorated, reground, reprocessed

- Styrenic based
  - Kraton, Monprene

- Olefinic based
  - Catalloy, Affinity

- Thermoplastic Urethane (TPUs)
  - Pellethanes, Elastollan, Texin

- Polyester based
  - Hytrel

- Polyamid based
  - Pebex

- TPVs (PP/EPDM)
  - Santoprene

- Melt Processable Rubber
  - Alcryn

- Synthetic Rubbers
  - NBR, EPDM, SBR
PRODUCT DESIGN BASICS

Wall Thickness considerations

Why is uniform wall thickness important?
• Sink marks, Warpage, Voids, Molded-in Stress, Long cooling time, Even material flow

What causes non-uniform wall thickness?
• Corners.................Add radii
• Transition areas..............taper over distance
• General Ignorance..........Get educated

Basic Rules
• Nominal Wall thickness - 0.250 or less
• Transition must be less than +/- 25% nominal wall thickness, gradual transition is the best
Material Selection Process

- Define requirements
- Narrow down choices...process of elimination...clear vs. opaque
- Rigid, flexible, elastomeric?
- Specific application? Medical?
- Material selection guidelines
- Specific property requirement...next slide
Identification Analysis

Why Identify?

- Competitive product identification
- Failure analysis
- Verification at later date
- Separation of Plastics by type for recycling/reprocessing
- Identify stored and unmarked materials, foils etc.
- Development of new materials
- Discover forgeries and imitations
- Validate material specification
Injection Molding

Machine Types
Toggle........... Small machines, Fast, High maintenance,
Hydraulic.......Large machines, Slow, more expensive
Electric......... Up to 500 Tons, Accurate, excellent repeatability,
50 to 70 percent less electricity consumption, low maintenance

Injection Unit
Clamping Unit

Machine Specifications..... Tonnage/Shot size
Tons/Oz

Injection Molding Cycle:
Mold Close – Inject – Hold – Cooling – Open – Eject
Multi-Material Molding (Coinjection)
Reaction Injection Molding (RIM)
Liquid Injection Molding (LIM)
EXTRUSION

CROSSHEAD EXTRUSION
Bare wire is fed across the melt flow, through the die, which controls the thickness of the wire insulation.
Blow Molding

Extrusion, Injection, Stretch Blow molding

Extrusion blow molding
Hot plastic is extruded downward between mold halves. This is the “parison”.

Injection-blow molding
Injection phase
TOOLING >>> Mold Types

Two Plate Mold

Three Plate Mold

Insulated Runner Mold

Hot Runner Manifold

Stack Mold
## SPI Mold Classifications

<table>
<thead>
<tr>
<th>Class</th>
<th>Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>1MM cycles or more</td>
</tr>
<tr>
<td>102</td>
<td>Not exceeding 1MM</td>
</tr>
<tr>
<td>103</td>
<td>Under 500,000 cycles</td>
</tr>
<tr>
<td>104</td>
<td>Under 100,000 cycles</td>
</tr>
<tr>
<td>105</td>
<td>Not exceeding 500</td>
</tr>
</tbody>
</table>
ASSEMBLY & SECONDARY OPERATIONS

- Ultrasonic Welding (Crystalline Vs. Amorphous)
- RF welding
- Spin Welding
- Solvent/Adhesive Bonding
- Mechanical Fastening
- Friction Fitting
Decorating & Printing

1. In standard open inkwell pad printing, the spatula scoops ink out of the inkwell and over the entire cliché plate surface with the doctor blade lifted off the surface.

2. The pad slide moves to the right as the doctor blade removes excess ink from the cliché.

3. The transfer pad, or tampon, is then pressed against the inked plate and lifted.

4. As the transfer pad (now holding image) moves left toward the object to be printed, new ink is deposited onto the plate.

5. With the new image now slightly tacky, the pad descends to the part, leaves the imprint, and the process is then repeated.
TESTING & FAILURE ANALYSIS

- Mechanical Properties
- Thermal Properties
- Electrical Properties
- Weathering
- Optical Properties
- Material Characterization Tests
- Chemical properties
- Flammability
- Failure Analysis
Photoelastic Pattern
PLASTICS PART COSTING

PART COST = MATERIAL COST + MOLDING COST + SET UP COST

PART COST = 2.24 $/PC

Material Cost = Part weight/454 * Material cost / material yield/100

<table>
<thead>
<tr>
<th>Part Weight:</th>
<th>454 grams</th>
<th>454/454 * 1.0 / .95 = \textbf{1.05} $/PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material cost:</td>
<td>1.00 $/#</td>
<td></td>
</tr>
<tr>
<td>Material Yield:</td>
<td>95 %</td>
<td></td>
</tr>
</tbody>
</table>

Molding Cost = Machine HR. Rate / 3600/Cycle time * No. of cavities / machine utilization/100 / process yield/100

<table>
<thead>
<tr>
<th>Machine Hr. Rate:</th>
<th>60 $/HR</th>
<th>60 / (3600/60*1) / .90 / .95 = \textbf{1.16} $/PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle time:</td>
<td>60 seconds</td>
<td></td>
</tr>
<tr>
<td>No. of cavities:</td>
<td>1 Cavity</td>
<td></td>
</tr>
<tr>
<td>Machine utilization:</td>
<td>90 %</td>
<td></td>
</tr>
<tr>
<td>Process Yield:</td>
<td>95 %</td>
<td></td>
</tr>
</tbody>
</table>

Set Up Cost = Set up cost / Order quantity

$ 300 / 10,000 = \textbf{0.03} $/PC
Where to Get More Information

BOOKS
SPE Book Store, www.4spe.org
IMM Book Club, www.immnet.com

SEMINARS
University of Massachusetts Lowell Continuing Studies and Corporate Education, Lowell, MA
www.continuinged.uml.edu/plastics
Society of Manufacturing Engineers, www.sme.org
SPE Educational Seminars, www.4spe.org
Techtrax, www.techtrax.net

TRADE PUBLICATIONS
Injection Molding Magazine, immnet.com
Plastics Engineering, www.4spe.org
Plastics Technology, www.plasticstechnology.com
Modern Plastics, www.modernplas.com

INTERACTIVE TRAINING PROGRAMS
Paulson Training Programs, Inc. www.paulson-training.com
A. Routsis Associates Inc. www.traininteractive.com
Molded-in Stress in Optical Polycarbonate Applications
Topics of discussion

- Current methods of measuring molded-in stresses in molded polycarbonates & Industry standards.
- How is this data being used?
- Pros and Cons of current testing methods.
- Industries perception – Perceived value or inconclusive?
Polycarbonate Solvent stress Analysis

**GE Plastics test Method T-77**

- This test, developed by GE plastics, is used mainly for evaluating residual stress in molded parts. The test can also determine effect of external stress or stresses resulting from molded-in inserts or press-fit items.

- The combination of two solvents, **Methanol** and **Ethyl Acetate**, is used in various proportions. Effect of this mixture on specimen is observed when exposed for specified time period.
Heat Reversion Technique

- This test is conducted by simply placing the entire specimen or a portion of the specimen in a thermostatically controlled, circulating air oven and subjecting it to a predetermined temperature for a specified time. The specimens are visually examined for a variety of attributes.

- The degree and severity of warpage, blistering, wall separation, fish scaling, and distortion in the gate area of the molded parts indicate stress level. Stresses and molecular-orientation effects in the plastic material are relieved, and the plastic starts to revert to a more stable form.

- The temperature at which this begins to occur is important. If changes start below the heat distortion temperature (HDT) of the material, high level of stress and flow orientation are indicated.
Principles of Photoelasticity

When polarized light passes through a material that is stressed, the light splits into two divergent polarized beams vibrating in different planes (x and y) along the direction of the principal stresses.

This phenomenon, which results in two different indices of refraction, is known as birefringence.
Principles of Photoelasticity

- By rotating the second polarizing filter (analyzer), the user can control the amount (intensity) of light allowed to pass through. The components of the two light waves that do pass through at any given angle of analyzer rotation interfere with each other, resulting in a characteristic color spectrum.
How to quantify the results.....

- **Qualitative**.....Visual, Best guess, interpretation variations
- **Quantitative**....reliable, measurable values, ASTM D 4093
- Manual measurement techniques
- **Equipment** : Polariscope or Polarimeter with compensator and Calibrated wedge

*We quantify this information.*
Links to articles….

- **Measuring Residual Stress In Transparent Plastics**
  [http://www.devicelink.com/mpb/archive/97/01/001.html](http://www.devicelink.com/mpb/archive/97/01/001.html)

- **Stress Crack Test: Makrolon moldings**

- **Polycarbonate: Molded Part Internal Stress**
PLASTICS FAILURE ANALYSIS AND TESTING

Vishu Shah
Consultek
Topics

Failure Analysis

Why do Plastics parts fail?
Reasons behind part failures
- Material selection
- Design
- Process
- Service Conditions

Types of Failures
- Mechanical
- Thermal
- Chemical
- Environmental

Testing
- Mechanical properties
- Thermal properties
- Electrical properties
- Melt Index test
- Color measurement
- Weathering Properties
- UL Flammability testing
- Material Identification Techniques
- End Product testing
Material Selection

Material Selection Pitfalls

• Datasheet interpretation
• Synergistic effects
• Economics
• Supplier Recommendations
• Application checklist
Failure resulting from improper material selection

Figure 4.35 Impact polystyrene ballpoint pen barrel that cracked first or second time pen was used
Design

Most Common Mistakes in Design of Plastics

• Non-uniform wall thickness
• Sharp corners, lack of radius
• Draft angle considerations
• Lack of Creep considerations
• Direct conversion from other materials

Figure 4-13: A. Acetal valve body design problem—photograph of interior ([1] Fig. 1, reproduced with permission). B. Diagram showing voids in acetal valve of Fig. 4-13A ([1] Fig. 2, reproduced with permission). C. Diagram showing improved design of acetal valve ([1] Fig. 3, reproduced with permission)
Most Common Process Induced Failures

- Drying of material
- Molded-in stresses
- Knit lines
- Degradation
- Shrinkage voids
- Regrind level
- Contamination
Service Conditions

Failures due to:

- "Reasonable" misuse......Examples
- Use of product beyond its intended lifetime
- Unstable/Unintentional/Unanticipated service condition
  - Thermal, Chemical, Environmental, Physical, Biological, Mechanical
  - Examples of unintentional service.....coffee can lid, cash drawer, one time short service..bags, cups
  - Examples of unexpected service......underground animals
- Service conditions beyond reasonable misuse
- Simultaneous application of two stresses operating synergistically
Types Of Failures

Mechanical
Thermal
Chemical
Environmental
Failure Analysis Steps & Tools

- Visual Analysis: Knit line, Degradation, Discoloration, User Abuse, Examination under magnifier, Broken surface
- Stress analysis, Photoelastic analysis, strain gage
- Simple tests: Material Identification
- Mechanical testing
- Nondestructive testing
- Advance Tests: FTIR, DSC, TGA Microtoming, Pyrolysis (Burn out)
IDENTIFICATION ANALYSIS

Why Identify?

- Competitive product identification
- Failure analysis
- Verification at later date
- Separation of Plastics by type for recycling/reprocessing
- Identify stored and unmarked materials, foils etc.
- Development of new materials
- Discover forgeries and imitations
- Validate material specification
MELT INDEX TEST

- Melt Index test measures the rate of extrusion of thermoplastic material through an orifice of specific length and diameter under prescribed conditions of temperature and pressure.
- Melt Index value is reported in grams per 10 minutes for specific condition.
- Distinguishes between the different grades of a polymer.
Information on Web

GENERAL INFORMATION

Web Watch directory
Plastics.com
.Commerx
Processzone.com
Polysort
GF Plastics Design Solution Ctr
Injection Molding magazine
Plastics News magazine
Modern Plastics magazine
Plastics Technology Magazine
Molding Systems
Macrogalleria
Medical Device Link
Qplastics.com
Studyweb
Plastics Mall
Vinyl World
Plastics Resource
Teaching Plastics

USEFUL LINKS

www.
plasticsnews.com/subscriber/webwatch/wwwindex.html
plastics.com
.commerxplasticsnet.com
processzone.com
polysort.com
geplastics.com/resins/designdsolution
immmnet.com
plasticsnews.com
modplas.com
plasticsindustry.com
moldingsystems.com
pmc.usm.edu/macrog/index.htm
devicefilm.com
qplastics.com
studyweb.com
plasticsmall.com
plasticsforum.com/vinylworld/index.html
plasticsresource.com
teachingplastics.org

MATERIAL SEARCH

Matweb
IDES
MSDS search
Conversion Help
Weight Calculator
SD Plastics
Plaspec material search

Excellent source for material search
Free data sheets
MSDS data sheets
Very useful conversion tool
Easy to use part weight calculator
Funny and useful website
Material selection database

matweb.com
freemds.com
msdsssearch.com
matweb.com/conversion.htm
matweb.com/weight-calculator.htm
sdplastics.com
plaspec.com
Local Failure Analysis Laboratories

KARS' ADVANCED MATERIALS, INC.
7271-CD Garden Grove Blvd. Garden Grove, CA 92841
(714) 892-8987 Fax: (714) 894-0225 kars@karslab.com

Seal Laboratories Inc.
250 N. Nash Street, El Segundo CA 90245 PH: 310-322-2011
www.seallabs.com

CRT Laboratories, Inc.
1680 N. Main Street, Orange, CA 92867 PH: 800-597-LABS
www.crtlabs.com
Plastics Identification & Material Selection Process

Vishu Shah
Consultek
IDENTIFICATION ANALYSIS

Why Identify?

- Competitive product identification
- Failure analysis
- Verification at later date
- Separation of Plastics by type for recycling/reprocessing
- Identify stored and unmarked materials, foils etc.
- Development of new materials
- Discover forgeries and imitations
- Validate material specification
SIMPLE METHODS OF IDENTIFICATION

Useful for identifying basic polymer and differentiating between the different types of polymers within the same family.

Requires no special equipment or in-depth knowledge of analytical chemistry.

Simple step by step identification procedure using flow chart.
Material Selection Process

- Define requirements
- Narrow down choices... process of elimination... clear vs. opaque
- Rigid, flexible, elastomeric?
- Specific application? Medical?
- Material selection guidelines
- Specific property requirement... next slide
Identifying Application Requirements

**Physical Properties**
- Specific Gravity
- Mold Shrinkage
- Rheology

**Mechanical Properties**
- Tensile Strength
- Tensile Modulus (Stiffness-Resistance to bending)
- Tensile Elongation/Ductility
- Impact strength
- Fatigue Endurance (Resistance to high frequency cyclic loading)
- Creep resistance (Resistance to long-term deformation under load)

**Thermal Properties**
- Deflection Temperature Under Load (DTUL,HDT)
- Thermal Conductivity
- Thermal expansion coefficient
- Continuous Use Temperature (Relative thermal Index)

**Regulatory Performance**
- Flammability (UL 94)
- High Voltage Arc Tracking
- FDA

Source: GE Plastics
New Application Checklist

This checklist includes critical considerations for new part development. Its use will help provide a more rapid and more accurate recommendation.

Name: __________________________ Date: __________________________
Customer: ______________________ Part: __________________________

Project timing
Driving force
Current product
Its performance

Comments:

**Part Function — What is the part supposed to do?**

**Appearance**

Clear
- [ ] water clear
- [ ] very clear
- [ ] generally clear
- [ ] transparent clear
  - maximum haze level:
- [ ] transparent color:
  - maximum haze level:

Comments:

Opaque
- [ ] high gloss
- [ ] medium gloss
- [ ] low gloss
- [ ] from the plastic
- [ ] from paint
- [ ] from the mold

Comments:

Colors desired:
- [ ] from the plastic
- [ ] from paint
- [ ] from both

Criticality of color match:
- [ ] daylight
- [ ] tungsten light
- [ ] fluorescent light
- [ ] all (no metamerism allowed)

Comments:

**Critical appearance areas — please attach sketch**

- gate bleaches: [ ] None [ ] Invisible [ ] Minor [ ] OK
- sink marks: [ ] None [ ] Invisible [ ] Minor [ ] OK
- weld lines: [ ] None [ ] Invisible [ ] Minor [ ] OK

Comments:

**Critical structural areas — please attach sketch**

Comments: __________________________

Monsanto Plastics
Where the best end products begin.
Material Selection

Previous Applications

Before addressing a detailed material selection process, it is often worthwhile to determine if a similar part has been made before, and if so, from which material it was made. If such an application exists, it may be advisable to conduct further investigation into the specifics of the particular application to see whether newer or more appropriate materials can now be used.

Since it is impossible to list all applications — some grades are used for a multitude of parts in many industries — a relatively limited number has been listed.

This Application Matrix provides an overview of some typical applications in some of the numerous market segments served by GE Plastics.

For further information on a particular grade, please contact your local GE Plastics representative.

Table 1-8. Application Matrix.

<table>
<thead>
<tr>
<th>Products</th>
<th>Automotive Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>CYCOLAC-ABS Resin</td>
<td>• ease of molding</td>
</tr>
<tr>
<td></td>
<td>• surface quality</td>
</tr>
<tr>
<td></td>
<td>• thermal stability</td>
</tr>
<tr>
<td></td>
<td>• impact resistance</td>
</tr>
<tr>
<td></td>
<td>• wide range of colors</td>
</tr>
<tr>
<td>CYCOLOY-PC/ABS Resin</td>
<td>• ease of molding</td>
</tr>
<tr>
<td></td>
<td>• very good flow</td>
</tr>
<tr>
<td></td>
<td>• low temperature impact</td>
</tr>
<tr>
<td></td>
<td>• very good indoor UV stability</td>
</tr>
<tr>
<td></td>
<td>• flame resistance</td>
</tr>
<tr>
<td>ENDURAN-PBT Resin</td>
<td>• chemical and stain resistance</td>
</tr>
<tr>
<td></td>
<td>• dimensional stability</td>
</tr>
<tr>
<td></td>
<td>• low water absorption</td>
</tr>
<tr>
<td></td>
<td>• very good processibility</td>
</tr>
<tr>
<td></td>
<td>• noise attenuation</td>
</tr>
<tr>
<td>GELQY-ASA Resin</td>
<td>• excellent weatherability</td>
</tr>
<tr>
<td></td>
<td>• heat resistance</td>
</tr>
<tr>
<td></td>
<td>• impact resistance</td>
</tr>
<tr>
<td></td>
<td>• aesthetic, colorability</td>
</tr>
<tr>
<td>GESAN-SAN Resin</td>
<td>• clarity</td>
</tr>
<tr>
<td></td>
<td>• chemical resistance</td>
</tr>
<tr>
<td></td>
<td>• very good flow</td>
</tr>
<tr>
<td></td>
<td>• thermal stability</td>
</tr>
<tr>
<td>LEXAN-PC Resin</td>
<td>• transparency</td>
</tr>
<tr>
<td></td>
<td>• high impact</td>
</tr>
<tr>
<td></td>
<td>• dimensional stability</td>
</tr>
<tr>
<td></td>
<td>• temperature resistance</td>
</tr>
<tr>
<td></td>
<td>• flame resistance</td>
</tr>
<tr>
<td>NORYL Modified PPO Resin</td>
<td>• electrical properties</td>
</tr>
<tr>
<td></td>
<td>• dimensional stability</td>
</tr>
<tr>
<td></td>
<td>• hydrolysis resistance</td>
</tr>
<tr>
<td></td>
<td>• temperature resistance</td>
</tr>
<tr>
<td></td>
<td>• low water absorption</td>
</tr>
<tr>
<td></td>
<td>• flame resistance</td>
</tr>
<tr>
<td>NORYL GTX-PPE/PA Resin</td>
<td>• on-line paintability</td>
</tr>
<tr>
<td></td>
<td>• low temperature impact</td>
</tr>
<tr>
<td></td>
<td>• temperature resistance</td>
</tr>
<tr>
<td></td>
<td>• chemical resistance</td>
</tr>
<tr>
<td></td>
<td>• low mold shrinkage</td>
</tr>
<tr>
<td>SUPEC-PPS Resin</td>
<td>• chemical resistance</td>
</tr>
<tr>
<td></td>
<td>• inherent flammability</td>
</tr>
<tr>
<td></td>
<td>• heat resistance</td>
</tr>
<tr>
<td></td>
<td>• high strength</td>
</tr>
<tr>
<td></td>
<td>• very good electrical properties</td>
</tr>
<tr>
<td>UTEMTPEI Resin</td>
<td>• chemical resistance</td>
</tr>
<tr>
<td></td>
<td>• temperature resistance</td>
</tr>
<tr>
<td></td>
<td>• dimensional stability</td>
</tr>
<tr>
<td></td>
<td>• inherent flammability</td>
</tr>
<tr>
<td>VALOX-PBT Resin</td>
<td>• very good electrical properties</td>
</tr>
<tr>
<td></td>
<td>• chemical resistance</td>
</tr>
<tr>
<td></td>
<td>• temperature resistance</td>
</tr>
<tr>
<td></td>
<td>• flame resistance</td>
</tr>
<tr>
<td></td>
<td>• fast molding</td>
</tr>
</tbody>
</table>

Dashboard components, center consoles, glove boxes, trim, vents, grilles, air conditioned controls, instrument clusters, speaker grilles, door linings, pillar trim, seat covers and knobs, ash trays, steering column covers, door handles, rearview mirror, instrument panel covers, center consoles, heater covers, instrument panel covers.
Material Supplier Data Sheets

- Material supplier data sheet - purpose
- Origination of data sheets
- Meaning of reported values
- How are the values generated
- Interpretation of the data
- Application of the data for practical use
Purpose of a data Sheet

- Compare property values of different plastics materials (Tensile strength of nylon vs. Polystyrene, Impact strength of ABS vs. Polycarbonate)
- Quality control guidelines for material manufacturers
- Purchasing/Material specifications
- Initial screening of various materials
Other Important Considerations

- Cost
- Product design
- Tooling
- Shrinkage
- Secondary Operations
- Assembly
- Interpreting Data Sheets
- Prototyping and Testing
Material Selection using Web

- Matweb  www.matweb.com
- I des  www.freemds.com
- Plaspec  www.plaspec.com
- Consultek  www.consultekusa.com
Plastics Part Design for Injection Molding

Vishu Shah
CURRICULUM

- Polymer Chemistry Basics and Material Selection Process
- Plastics Material Identification Techniques
- Concurrent Engineering, Plastics Part Design Process overview
- Manufacturing Considerations - Design For Molding
- Manufacturing Considerations - Design For Molding
- Basic Part Design
- Basic Part Design
- Basic Part Design, Prototyping and Testing
- Design For Assembly and review of assembly techniques
- Tooling Considerations
CONCURRENT ENGINEERING

Sequential engineering - "over the wall approach"

Parallel approach to product development
"concurrent engineering"

Figure 3.4. "Parallel" or "Concurrent Engineering" approaches to product design reduce development time, improves quality, and minimizes the potential for unanticipated production or performance problems.
Manufacturing Considerations For Injection Molded Plastic Parts

Design For Manufacturing/Molding (DFM)

- Mold filling
- Weld lines / Knit lines
- Shrinkage
- Ejection
Basic Part Design

Wall Thickness considerations

**Why is uniform wall thickness important?**
- Sink marks, Warpage, Voids, Molded-in Stress, Long cooling time, Even material flow

**What causes non-uniform wall thickness?**
- Corners..............Add radii
- Transition areas...........taper over distance
- General Ignorance.........Get educated
- Outright stupidity..........Genocide??????

**Application Requirements**
- Structural requirements, strength, impact, fatigue etc influenced by wall thickness
- Electrical loads also impact on wall thickness

**Moldability**
- Size of the part and ability of the material to fill determines the minimum wall thickness

**Agency requirements**
- Must meet minimum wall thickness specifications...example...UL flammability rating

**Cost and performance considerations**
- Current threshold is approx 1 mil or .040 inches
- Thin wall molding techniques
THE DIVINE 66% RULE

The thickness of ribs should never exceed 66% of the nominal wall thickness.

If your ribs never exceed 50-66% of nominal wall thickness you will never have a problem with sink.
There are two primary moldability factors to consider when designing bosses.

1. Avoiding sink
2. Ejection feasibility

Note that the boss wall is 66% of the nominal wall thickness. The core pin up the center penetrates 50-66% of the way through the nominal wall.

Note the circular sink marks created by the failure to properly core out the boss.
Threads

- Threads must have radii...no flat or “V” notched at root and crest
- Pitch should be less than 1/32 in.
- Lead depth must be greater than 1/32 in.

MOLDED-IN THREADS

- AVOID
- PREFER

1/32" Lead-In

Thread Profiles

- American National (Unified)
- Acme
- Buttress

Designing with Clearance on Threads

<table>
<thead>
<tr>
<th>WRONG</th>
<th>RIGHT</th>
<th>WRONG</th>
<th>RIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Wrong Thread Design" /></td>
<td><img src="image2" alt="Right Thread Design" /></td>
<td><img src="image3" alt="Wrong Thread Design" /></td>
<td><img src="image4" alt="Right Thread Design" /></td>
</tr>
</tbody>
</table>

Common thread profiles used in plastic parts.
PROTOTYPING TECHNIQUES

- Hand fabrication and machining
- Printing (Solid Object printer)
- Stereo Lithography (SLA)
- Selective Laser sintering (SLS)
- Part Casting techniques
- Soft tooling
- Hard tooling
All about RP
www.cc.utah.edu/~asn8200/rapid.html

WELCOME TO THE RAPID PROTOTYPING HOME PAGE
"Your link to the world of Rapid Prototyping" since July, 1995

Last update: February 13, 2002. This document is updated frequently in an effort to keep up with the latest developments in the fast paced field of Rapid Prototyping (aka Desktop Manufacturing, Solid Freeform Fabrication, or Layered Manufacturing). The * sign indicates items that have been added since the last update.

Also visit: The Rapid Tooling Home Page.

TABLE OF CONTENTS

Commercial Rapid Prototyping Systems
Concept Modelers
Resellers of Concept Modelers and RP Systems
Commercial Service Providers
Consultants
Academia and Research
Publications and Conferences
Magazine Articles
Biomedical uses of Rapid Prototyping
Art via Rapid Prototyping
Software for the Rapid Prototyping Market
Professional Associations
Other Valuable Resources
How can one design a part so that tooling is:

- Easy to build
- Cost effective
- Efficient in terms of cycle time and operation
- Less complex
- Long lasting
Design For Assembly (DFA)

Advantage PLASTICS

- Variety of fastening methods........Press fit, Snap fit, Bonding, Welding
- Ability to manufacture complex geometries
- Ability to use various manufacturing processes
- lower cost assembly techniques
- Automation
- No post secondary operations (Such as deburring, finishing)
- Reduce number of components
- Lower overall product cost
Press Fit Assembly

Material Considerations

• Ductile materials preferred
• Low stress level desired (Calculate)
• Use materials with similar coefficient of thermal expansion

Design Considerations

• Use interference limit graphs from material suppliers
• Draft angle as small as possible
• Smooth Vs. knurled or splined shaft

Figure 6.3. Core pins with excessive draft result in non-uniform stress distributions for press fit hubs. Hubs with zero draft are more difficult to mold. The telescoping core pins offer a balance in terms of stress distribution and moldability.
Part Design to Enhance Flow and Shape

Design part with ample curve to enhance flow

Design part with minimum number of projections and cored sections

Figure 3–10. Streamlining of the plastic part will help to prevent gas pockets.
Tooling for Injection Molding

Vishu Shah
Curriculum

- Polymer Chemistry - Plastics materials
- Injection Molding process
- Tooling Considerations
  - Mold Metallurgy, Runners, Gates, Sprue bushing, Sprue pullers
- Mold Design and Simulation software
- Tooling considerations
  - Cooling, Venting
- Tooling Considerations
  - Draft angles, Shrinkage, Mold polishing, Tool surface enhancement
- Hot runner systems
- Rapid tooling techniques
Screw - Barrel - Check Ring

**Screw Material**
- Nitrided
- D2

**Barrel materials**
- Nitrided
- Bimetallic
Types Of Molds

- Two plate mold
- Three Plate mold
- Insulated hot runner mold
- Hot runner mold
- Stack mold
Hot Runner (Runnerless) Molds

In the hot runner mold, the runners are kept hot in order to keep the molten plastic in a fluid state at all times. This is a “Runnerless” molding process and hence the name. Hot runner molds are similar to the three plate molds, except that the runner section of the mold is not opened during the cycle. The heated runner plate (Manifold) is kept insulated from the rest of the relatively cooler mold.

- No runner to separate from the molded parts
- No runners to either dispose of or regrind and reprocess
- Less possibility of contamination
- Hot drops carry consistent heat at processing temperature directly into the cavity
- Lower cycle (cooling) time – cooling time not runner dependent
- No robotics (or automation) needed for runner removal
- Possibly lower injection pressure
- No sprue/runner sticking problems
- Cleaner molding environment
- 3 Level Stack Mold

- QPC design expandable to 4 level Stack Mold
- 50% Increase in production over conventional 2 level stack molds
- Fits into extended machine Shut Heights available today
- Fully balanced Hot Runner System using Triple VMTS Technology
- Suitable for Deep Draw Parts
- Series Centering Mechanism
Major categories of applications in molds

- Mold Cavity and Core unit components
- Mold base plates
- Special function components (Slides, gibs, wear plates)

Material selection considerations

- Type of plastics to be molded....abrasive, corrosive etc
- Number of parts to be molded
- Surface finish of molded parts
- Cavity design requirements...metal to metal contacts etc.
- Method of cavity forming...Machining requirements
- Method of heat treating
Recommended runner sizes

Runners

*Full round* runners are the most efficient for minimizing heat loss and pressure drops. *Trapezoidal* runners are satisfactory when dictated by design. *Half round* runners are not recommended. The diameter of the runner for various lengths of flow is shown in Figure IV.

**RUNNER SIZES**

<table>
<thead>
<tr>
<th>Sprue</th>
<th>L</th>
<th>Primary Length (L)</th>
<th>Primary Diameter (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10” Long or Above</td>
<td>.375”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3”–10” Long</td>
<td>.312”</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3” or Under</td>
<td>.250”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary Length (l)</th>
<th>Secondary Diameter (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3”</td>
<td>.250”</td>
</tr>
</tbody>
</table>

**Figure IV**

**Runner Sizes**

1” to 2” Long  
1/4” Full Round

2” to 4” Long  
3/16” Full Round

4” to 8” Long  
3/8” Full Round

8” up, 1/2” Full Round

**Mold Center Line**

**Mold Balance**

Not Recommended  
Suggested
Types of Gates

- Sprue Gate...used on large single cavity parts, cold slug issues
- Edge gate...Large surfaces, thin wall, keep parts attached
- Fan gate...minimize surface imperfections, reduce stress
- Sub gate...(Tunnel gate)...Automation
- Diaphragm gate...round part, avoid weld line
- Flash gate...similar to fan gate...much wider, low warpage
- Ring gate...hollow tubular parts, helps with core shift
- Tab gate...stress free part and optical clarity...acrylic lens
- Sub gate into ejector pin...no gate marks
Gating Considerations

**Land Length**: 0.040 max. Long land length creates excessive pressure drop, part filling problem

**Steel safe**: Start small and increase as needed

**Gate size**: Larger the gate..lower the stress

**Gate placement**: Cosmetic issues, Jetting
### Sizing Vents

**Figure 2** Parting Line Venting

**Table 1** Vent dimensions — mils* (mm)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Depth</th>
<th>Land</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Delrin&quot; acetal resin</td>
<td>1.5-2 (0.038-0.05)</td>
<td>40 (1.0)</td>
</tr>
<tr>
<td>&quot;Zytel&quot; nylon resin</td>
<td>0.5-1 (0.013-0.025)</td>
<td>30-60 (0.75-1.5)</td>
</tr>
<tr>
<td>&quot;Minlon&quot; engineering thermoplastic resin</td>
<td>2 (0.05)</td>
<td>30 (0.75)</td>
</tr>
<tr>
<td>GRZ (glass-reinforced &quot;Zytel&quot; nylon) resin</td>
<td>2 (0.05)</td>
<td>30 (0.75)</td>
</tr>
<tr>
<td>&quot;Rynite&quot; polyester resin</td>
<td>2 (0.05)</td>
<td>30 (0.75)</td>
</tr>
</tbody>
</table>

*1 mil = 0.001 inch

Width: As wide as possible
- Minimum 0.125

Depth: 0.0005 to 0.002
- Ask material supplier

Land: As short as possible

Relief slot (vent channel):
- Minimum 20 x depth

Amount: 30% of the perimeter of the part

**VENT THE RUNNER….
YOU CAN’T HAVE TOO MUCH VENTING!!!!!**
Mold cooling

Tool Design/Cooling

- How does cooling work?
  - There are three methods for exchanging heat.
    - Radiation
    - Convection
    - Conduction
  - Hot plastic enters the mold, the heat moves by convection through the plastic until it comes to the surface of the mold.
  - The heat is then conducted through the mold to the water cooling channels.
  - There is a substantial amount of the heat that reaches the outside of the mold and is lost by radiation.
Flow rate

Minimum flow rate (GPM)

For good Reynolds Number (turbulent flow)...

Minimum GPM = 3.5 x pipe I.D.

Example:

• Ten ½” lines in parallel

• All equal lengths into common manifolds

Min. GPM Required = ½ x 3.5 x 10 = 17.5*

* Does not take into account heat load required to remove total heat from Plastic material.

Alternate Rule of Thumb: 7/16’ Diameter Waterline requires 1.5 GPM to achieve turbulent flow.
Why do crystalline material have greater shrinkage than amorphous materials?

As the melt cools and changes from liquid to solid, there is a substantial decrease in specific volume in crystalline materials due to the crystalline structure of the polymer and therefore greater shrinkage.
PROTOTYPING TECHNIQUES

- Hand fabrication and machining
- Printing (Solid Object printer) 3D Systems
- Stereo Lithography (SLA) 3D Systems
- Selective Laser sintering (SLS) 3D systems
- Fused Deposition Modeling (FDM) Stratasys
- Part Casting techniques
- Soft tooling (Machining, Keltool, SLS process)
- Hard tooling
Scientific Injection Molding

Vishu Shah
What is Scientific 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
- Every decision Must be backed by scientific data
CURRICULUM

- Polymer Chemistry Basics
- Part Design Fundamentals
- Overview of Basic Injection Molding process
- Drying, Material mixing, Coloring, Regrind Usage
- Major Process variables
- Decouple Molding, Universal Set Up Sheet
- Tooling Considerations, Venting, Cooling, Ejection
- Cycle Time Optimization, and Trouble shooting techniques
- Mold Flow Analysis, Productivity Improvements
- Modern Injection Molding Operation
Injection Molding…..simplified

Injection molding is a dynamic, non-linear process consisting of four sequential stages: plastication, filling, packing and ejection. In its simplest form an injection molding machine can be regarded as a large hydraulic pump, which, by virtue of a hydraulically controlled ram: transforms solid thermoplastic pellets into molten polymer (plastication), injects molten polymer into the mold cavity (filling), and pressurizes the cavity during polymer solidification (packing). Once the molded part has taken its final shape and allowed to cool, the mold is opened (ejection) and the process repeated.

3 M’s and 3 F’s
Material is MELTED.........MI XED....&.........MOVED
FLOWED (INJ ECTED).........FORMED........&...........FROZEN (COOLED)

Source: Moldflow article
Source: GE Plastics)
Fountain flow

Mold filling is non-isothermal process involving laminar fountain flow and solid layer formation at the cavity and core walls due to the effects of conductive cooling.
**Materials Drying**

**Why do we need to dry Plastics Materials?**

All Plastics, when exposed to atmosphere, will pick up moisture to a certain degree depending upon the humidity and type of the polymer.

<table>
<thead>
<tr>
<th>Hygroscopic</th>
<th>Non Hygroscopic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymers with high affinity for moisture</td>
<td>Polymers with very little or no affinity for moisture</td>
</tr>
<tr>
<td>Moisture is absorbed into the pellet over time until equilibrium is reached</td>
<td>No absorption of moisture into the pellet. May pick up surface moisture.</td>
</tr>
<tr>
<td>Nylon, ABS</td>
<td>Polystyrene</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>Polyethylene</td>
</tr>
<tr>
<td>Polyester</td>
<td>PVC, Polypropylene</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>Acetal</td>
</tr>
<tr>
<td>Desiccant Dryer</td>
<td>Hot Air Dryer</td>
</tr>
</tbody>
</table>
L/D and Compression Ratio

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

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

Figure 4C

Compression Ratio

GP Materials  3:1
PVC           1.4:1
Acetal        4:1
Major Process Variables

- Temperature
- Flow Rate (Injection velocity)
- Pressure
- Time

Interdependence of Variables ........
Flow rate

All Plastics exhibit Non-Newtonian behavior………

Newtonian: Shear rate has no effect on viscosity……..Water

Non –Newtonian: Viscosity varies with shear rate

Plastics material’s viscosity decreases as shear rate increases

WHY IS THIS IMPORTANT??????

• Screw speed……..Lower viscosity at higher screw rpm

• Injection speed…..Flows easier with higher injection speed

Flow rate (Injection speed, velocity) = Time in seconds, measured from start of injection to transfer to pack/hold
Hydraulic pressure Vs. Plastic pressure

Hydraulic pressure: measure of how much force a machine can generate against the ram.

Plastic (Melt) Pressure: Pressure generated in the nozzle of a molding machine usually derived from the intensification ratio of the machine.

Cavity Pressure: Actual pressure in the cavity (Mold).
Cooling time

Mold cooling accounts for more than two-thirds of the total cycle time in the production of injection molded thermoplastic parts.

Cooling time is a function of:

- mold wall temperature
- melt temperature
- material properties
- part wall thickness
Decoupled molding

- Conventional Molding
  Injection ------ Pack ------ Hold

- Decouple Molding
  Decouple
  Injection -------------------------------- Pack and Hold
  From
  Fill -------------------------------- Pack and Hold

  95% ----------------------------------------- 5%
# Universal set up card

<table>
<thead>
<tr>
<th>Actual Melt temperature</th>
<th></th>
</tr>
</thead>
</table>

**Fill Data:**
- Time __________
- PPSI __________
- Weight _______

**Pack & Hold Data:**
- Time __________
- PPSI __________
- Weight _______

**Cooling data:**

**Temperatures**

**Pressures (PSI)**

**Flow rate (GPM)**
The Universal Setup Card

Mold number, number of shots to date, part name, customer, date, molder's name, and any other information your plant may require.
Fill time for a part 95 to 99 percent full.
Weight and picture of part 95 to 99 percent full.
Transfer volume, transfer position, or cavity pressure (time and hydraulic pressure transfer modes are not recommended).
Nozzle melt pressure range for different lots at transfer volume, position, or cavity pressure.
First stage set melt pressure (nozzle); this is first stage set pressure times the intensification ratio.
Cycle time.
Quoted cycle time(s).
Gate seal time.
Pack and hold time.
Pack and hold melt pressure.
Shot size in volume.
Mold temperature, cooling channel map.
Water flow diagram, with gallons/minute of each channel, temperature of water in and out, and water pressure in and out.
Screw run time (average).
Mold open and closed time, cure time, or cooling times.
Melt temperature via hot probe.
Nozzle tip length, diameter, land length, radius, and type.
Hydraulic pressure vs. time response curve.
Cavity pressure integral at the gate and end of fill.
Automation in Injection Molding

Tooling………….Subgates, Hot Runners
Part separators
Regrind feedback
Robotics
“Lights Out” Molding
MICRO INJECTION MOLDING

Vishu Shah
Consultek
Topics

- What is “MICROMOLDING”
- Markets and applications for micromolding
- Machines for micromolding
- Materials for micromolding
- Tooling for Micromolding
- Part Extraction challenges
- Part Inspection
- What next?
How small is small?

1 Nanometer = 0.001 micron
1 micron = 0.00004 in.
25 micron = 0.001 in.
50 micron = 0.002 in. Size of a human hair
1 mm = 0.040 in.

WHAT DEFINES A "MICRO" PART?

Less than 1/8 " overall dimension

For example, here are just some dimensions of microparts:

• Total part length of .060" (1.5mm)
• Gates down to 0.002" (0.05mm)
• Core pins of 0.0045" (0.11mm)
• Wall thickness down to .0015" (0.04mm)
• Cavity and Core TIR less than .0001" (.003mm)
• Overall part volume of 0.00013 grams
• 520 parts per plastic pellet!
Markets and applications for micromolding

Microdrive Systems and Control

Potentiometer Gear
Material: PPA

Part weight: 0.0008 g Acetal
Stepper Motor axle for Watches

Gears
Injection Molding Machines for Micromolding

Typical concerns......

- Material Plasticizing (Plastification)
- Material feeding
- Consistent shot size using standard check ring (reproducibility)
- Material freezing due to extremely small mass
- Shot size generally too large for micro parts
- Material degradation from long residence time
- Melt homogenization
- Static electricity Issues
Injection Molding machine designed specifically for Micromolding

Clean room Module
Optical inspection module
Ionization module
Part extraction (Handling) module
Packaging Module
Materials for Micromolding

- LCP (Liquid Crystal polymers)
- Acetal
- Polyester
- Polycarbonate
- PEEK
- Glass and Mineral filled compounds adds to the rigidity and stability
- Hygroscopic materials like Nylons are not suitable for micromolding since they change size making it difficult to hold close tolerances
Tooling for Micromoldling

Challenges in micro mold construction

- Physical limitation to how small one can cut or burn something, established by the geometric characteristics of the feature being formed
- Shear strength of the steel can not resist the pressures exerted by cutting head or in case of EDM surface finish is eroded beyond acceptable level
- Mechanical, thermal and chemical properties of the material being formed are affected
Tooling: LIGA technique

Limitations:
- Only vertical side walls possible
- Structures up to 1.5mm high only
- No draft allowed
Part Extraction Material handling and packaging

- parts too light to fall out of the mold
- Static electricity issue
- Special robotics and vacuum extraction into small tubes
- “Reel to Reel” methods such as one used in semiconductor industry
- Assembler unwilling to pick parts one at a time out of a plastic bag
- Bowl fed or vibratory automated assembly systems tend to jam up
Part inspection

Video measuring system

OGP SMARTSCOPE
Resolution: 0.00025 mm (0.00001”) Standard
0.00001 mm (0.000004”) optional

SEEBREZ  6 x 6
Resolution: 0.0005 mm (0.00002”) STD
0.00001 mm (0.00001”) OPT
Quality control solutions Inc.
Future of Micromolding

What comes first?........ Chicken or the Egg???
How big is the market for micromolded parts?
Nano Technology.....Are we there yet?
(1 nanometer = one millionth of a mm or .001 micron)

- New territory for both molder and mold maker
- Lots of trial and error
- Propitiatory technology and expertise developed
- Prepare to spend R & D money and time
Molders specializing in Micromolding

ALC Precision (American Laubsher Corp.) NY
Accumold, IA
Micromold, Inc. CA
Makuta technics, IN
Precimold Inc. Canada
Rolla AG, Switzerland
American precision Products, AL
Sovrin Plastics, UK
Stack Plastics, CA
Micro Precision Products, CA
Stamm, Switzerland

www.alcprecision.com
www.accu-mold.com
www.micromoldinc.com
www.makuta.com
www.precimold.com
www.rola.ch
www.injection-moldings.com
www.sovrin.co.uk
www.stackplastics.com
www.microprecisionproducts.com
www.stamm.ch
Energy Efficient Injection Molding Operation

Babu Joseph
Edison

April 17, 2003

Vishu Shah
Consultek
## Energy Efficiency

- **EFFICIENCY - KWH / KG OF POLYSTYRENE**

- **1 KWH / KG = 45.4 KWH / 100 POUNDS**

### Hydraulic

<table>
<thead>
<tr>
<th>Fixed</th>
<th>V.V / V.S</th>
</tr>
</thead>
<tbody>
<tr>
<td>KWH / KG</td>
<td>0.82 TO 1.25</td>
</tr>
</tbody>
</table>

### Semi-Hydraulic

- **HYBRIDS / PARTIAL ELECTRICS**
  - KWH / KG: 0.4 TO 0.6
- **ALL ELECTRICS**
  - KWH / KG: 0.2
All Electric Molding Machines

• Technology developed in early 1980 in Japan
• Introduced in USA by Milacron in 1985 at NPE
• Initially available in 50 to 150 tons sizes only
• Today up to 2000 ton all-electric machines available
• Term All-Electric implies use of servomotors on both clamp and injection end
• 10 to 20% higher in cost
• Over 30 machine manufacturers offer all-electric machines

• #1 advantage…..Energy Savings
All Electric Molding Machines

- Energy savings form 25% to 60%
- Repeatability, Accuracy, Consistency
- No hydraulic oil...clean
- No cooling water cost
- Quiet
- Low maintenance

- Higher cost
- Torque related issues...Long Hold times...PVC
- Unscrewing molds?
- Core Pulls?
## Side by Side Comparison

<table>
<thead>
<tr>
<th></th>
<th>Electric</th>
<th>Hybrid</th>
<th>Toggle / Hydraulic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>Best</td>
<td>Better</td>
<td>Good/Poor</td>
</tr>
<tr>
<td><strong>Accuracy/Repeat ability</strong></td>
<td>Highest</td>
<td>High</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Cleanliness</strong></td>
<td>Excellent</td>
<td>OK</td>
<td>poor</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>Low???</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Use of existing molds</strong></td>
<td>Low adaptability</td>
<td>Easy</td>
<td>Easy</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>
Energy savings With Variable Speed Drives

According to Plastics Technology, the hydraulic pump-motor(s) account for 80% of the total energy usage on an injection molding machine.

Even during periods of low hydraulic demand a maximum fixed-volume flow is produced. An example of the wasted energy at low demands is during the cooling stage of the cycle. During this cooling stage of the cycle, the motor(s) only need 20% rpm. The fixed-speed system wastes considerable amounts of energy by making inefficient use of the hydraulic pump-motor(s).

The motor conversion, from fixed-speed to variable-speed, enables the open loop injection molding process to be dependent on the demand for hydraulic fluid power. In return, there is a reduction in the use of kilowatt (kW) energy.

The basic concept of the system is simple: if the machine does not need the oil, don't pump it in the first place.
Energy savings with Auxiliary Equipment

Auxiliary equipment account for 20% of the total energy consumption

• Dryers
• Grinders
• Mold heaters
• Chillers
• Water Management
Energy Savings Measures

- Use of hot return air for desiccant regeneration
  - Example...Moton Luxor line of Dryers

- Use of sensors and controls
  - Lower drying temperature when not in use

- Honeycomb rotary bed
  - Crystallized molecular sieves baked on to drying wheel
  - Efficient moisture absorption
  - Low air pressure (smaller bower)
  - Faster drying time
  - No dust

- Low pressure dryer (Vacuum dryer)
  - At low pressure boiling point drops to 133° F
  - Low temperature and vacuum removes moisture faster

- Compressed air – no desiccant dryer
  - Uses hot and compressed air to remove moisture
  - No regeneration heaters

Cactus dryer
Granulators

- Shut-down method (Watt Wattcher From IMS co.)
- Voltage reduction method (Performance Controller\MPG)
- RPM reduction

With the controller in operation, amps consumed while grinding various materials and the phase unbalance has been dramatically reduced.

50% reduction in Power consumption
Insulation Blankets

- Fast Start up
- Even Heat Profile
- Personnel Protection
- Extended Heater Band Life

30% energy savings

**3 Year Comparison**

<table>
<thead>
<tr>
<th></th>
<th>Uninsulated</th>
<th>Insulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 year</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Drool protection Disk or cover

200 Ton Milacron
Common Sense Approach

- Hot Runners Molds
- Long hold times……Gate freeze studies
- Multiple ejection
- Parts on the floor
- Material on the floor
- Insulated Dryer hoppers
- Leaky Dryer and air Hose
- Oil leaks
- End of jobs….turn off power
Gas Assist and Microcellular (MuCell®) Molding Process

Vishu Shah
Consultek
Gas Assist injection molding is a process enhancement to conventional injection molding, involving the injection of high pressure nitrogen gas into the resin melt stream immediately after injection of the resin. The intent is not to cause mixture of nitrogen and resin, but for the nitrogen to displace resin in gas channels and thicker sections of the molded product. The process is a high speed, low pressure injection method, enabled by short shooting the tool, and completing the resin filling phase by nitrogen gas, at a much lower pressures as compared to convention injection molding.
Advantages of Gas assist Molding

- **Cycle time reduction and lower production costs**
  - Lower clamp tonnage
  - Lower injection pressures
  - Faster cycle due to hollow sections vs. solid section

- **Design Freedom**
  - Large ribs possible and permissible
  - Long flow lengths without multiple drops

- **Quality Improvement**
  - Lower stress within the part
  - Better dimensional stability and part to part size variations
  - Elimination of sink marks and warpage and voids
  - Greater strength and rigidity
  - Reduced knit lines (No multiple drops necessary)

- **Material savings through weight reduction**
  - Hollow parts

- **Simplification of Tooling**
  - Elimination of lifters and undercuts
Gas Assist Process Basics

- **Short-shot molding.** A process in which certain features such as ribs or thick walls are cored out with gas in an otherwise solid molded part. This process gets its name from the method of only partially filling the cavity during the polymer injection phase of the cycle and then relying on the gas injection phase to fill out the remainder of the cavity with the material the gas bubble is displacing from the core.

- **Full-shot molding.** A process in which the mold is completely filled during the plastic injection phase. Gas is introduced into the cavity in this case only to provide local packing and to compensate for the effects of polymer volumetric shrinkage as the part cools.

- **Hollow molding.** A process in which all or nearly all of the part is cored out by the gas, in effect making the part itself the gas channel. This is the method most often used to make parts with large cross sections such as rods, tubes, and handles.
Gas Delivery System

- Nitrogen Bottles
- Nitrogen Generators
- Central Nitrogen Systems
Part Design for Gas Assist

- Sizing of gas channels
- Gas channel layout
- Location of gas injection point(s)
Tooling Considerations

**New Tooling**

Injecting Through nozzle
- Sprue gate preferred
- Gate size and location is critical
- Cannot use hot runner system

Injecting in Runner/part
- Hot runner ok…
- Gas pin location very critical

**Converting Existing tooling**

Conventional Tooling
- Same considerations as new tooling

Hot Runner Tooling
- A) Inject gas through pins
- B) Eliminate hot runner

Venting, Cooling Shrinkage……..No special considerations
MuCell® Microcellular Technology

MuCell is the trade name of microcellular polymeric foam produced by Trexel’s proprietary MuCell microcellular foam process. The MuCell process uses supercritical fluids (SCFs) of atmospheric gases—not chemical blowing agents to create evenly distributed and uniformly sized microscopic cells throughout a thermoplastic polymer.

1. Granulate feeding
   The rotating screw draws in the granulate from the material hopper and transports it in the direction of the screw tip.

2. Transport and melting
   The plastic is platified and homogenized by heating while being transported.

3. Gas injection and mixing
   The gas is injected into the polymer melt and mixed.

4. Injection into the cavity
   The plastics-gas mixture is under pressure and is injected into the injection moulding tool, where it forms small, finely distributed gas bubbles.

Micrograph showing average cell size of 10 microns (.0004 Inches)
MuCell Injection Molding Machine

- Runs in both solid and MuCell molding

MuCell Interface Kit

SCF Delivery System
Applications

Weight reduced 10%
Cycle time - 20% - 30%
Machine size reduction up to 50%

HP Printer Chassis
Cycle time - 27%
Weight reduced - 8.5%

Cycolac CRT 3370 ABS - glass filled
In-Mold decoration

Conventional
Mucell