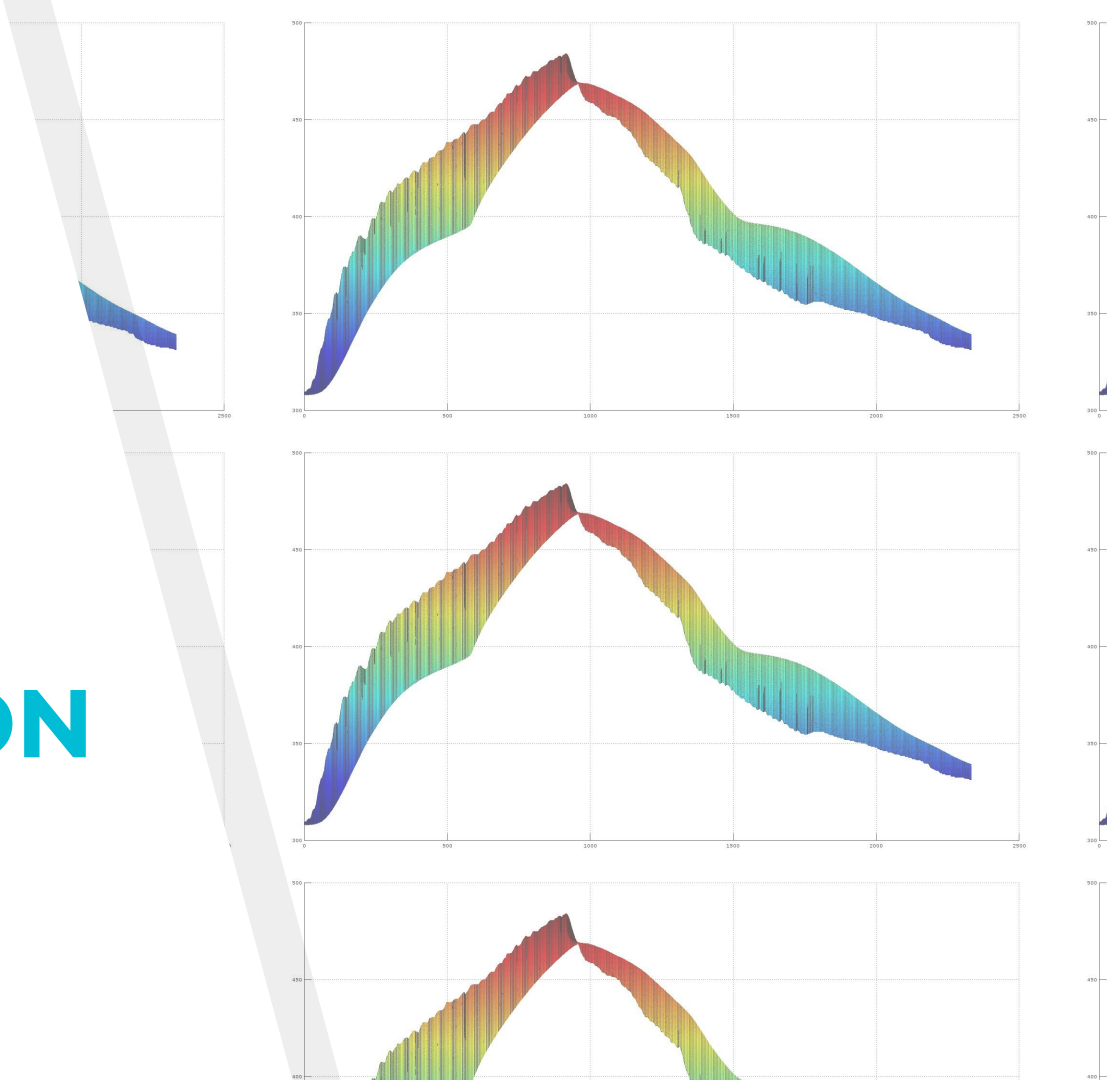
PROCESS OPTIMIZATION PROGRAM



ROTO MOLDING INDUSTRY

THE ROTO PROCESS MUST EVOLVE AND ADVANCE

Competitive processes, demanding applications, automation opportunities, work force availability…

CENTRO INC.
WORLDWIDE LOCATIONS

INDUSTRY LEADING ROTOLOPERM® TECHNOLOGY

INTRODUCTIONS

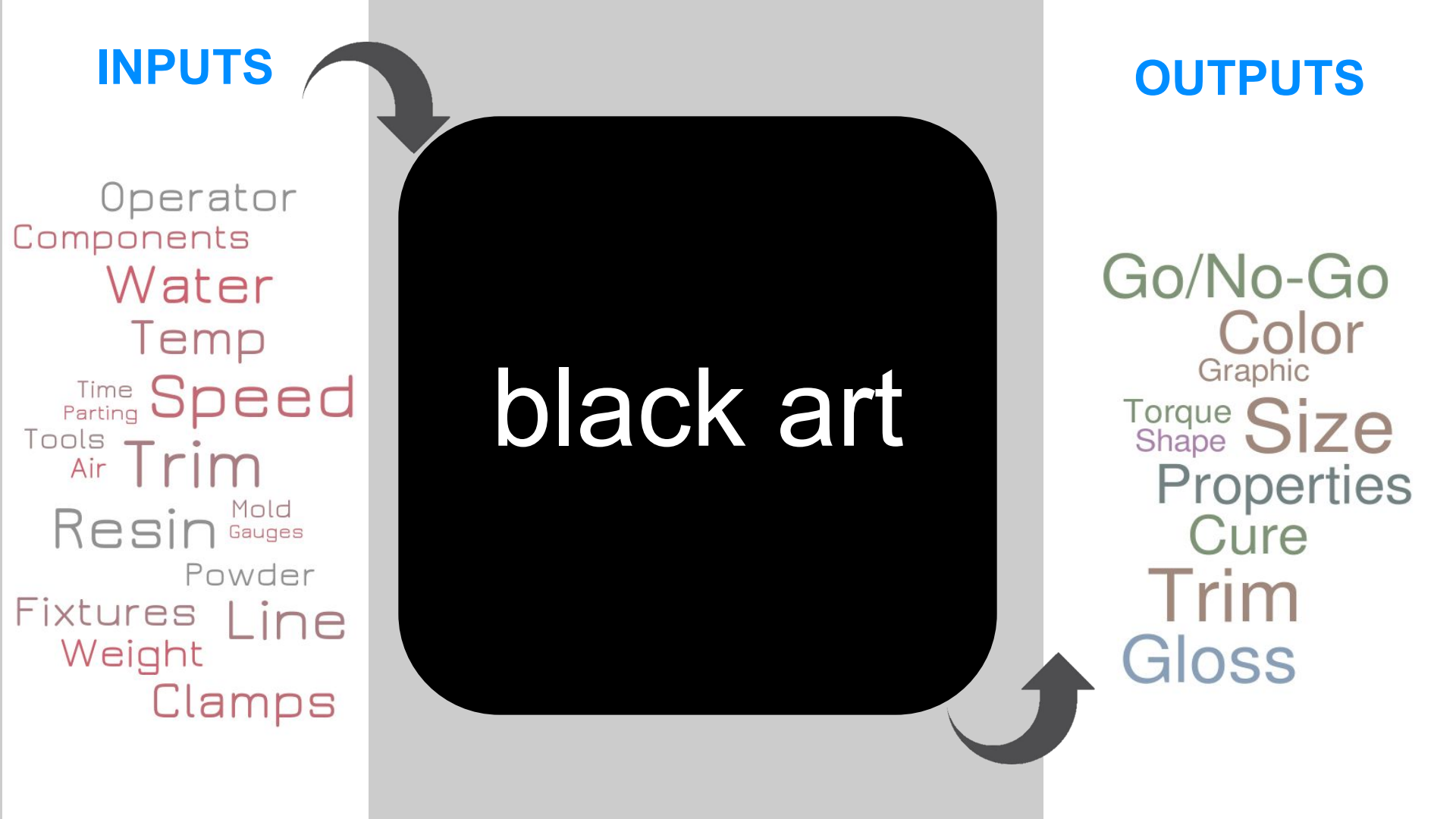
Centro Inc. R&D

Dan Grimes – Advanced Technology & Resin Leader
Shawn Trosen – R&D Intern

XLPE

FROM ART TO SCIENCE

Deep dive


INPUTS
Operator
Components
Water
Temp
Time
Parting
Speed
Tools
Air
Trim
Resin
Mold
Gauges
Powder
Fixtures
Line
Weight
Clamps
black art
OUTPUTS
Go/No-Go
Color
Graphic
Torque
Shape
Size
Properties
Cure
Trim
Gloss

INPUTS

Operator
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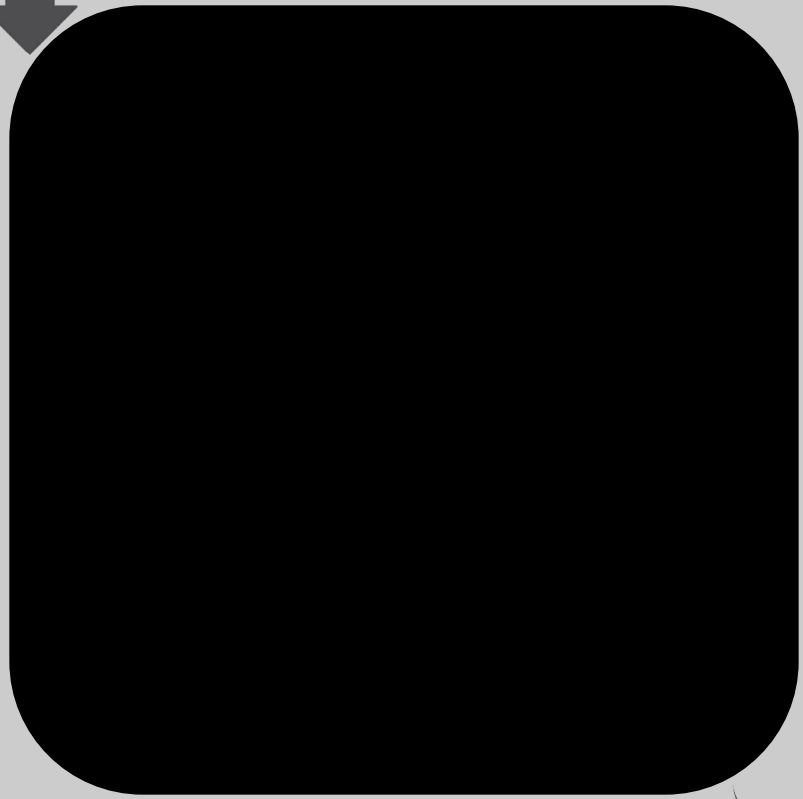
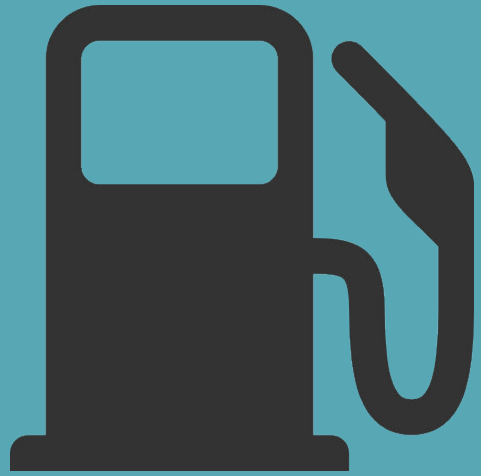
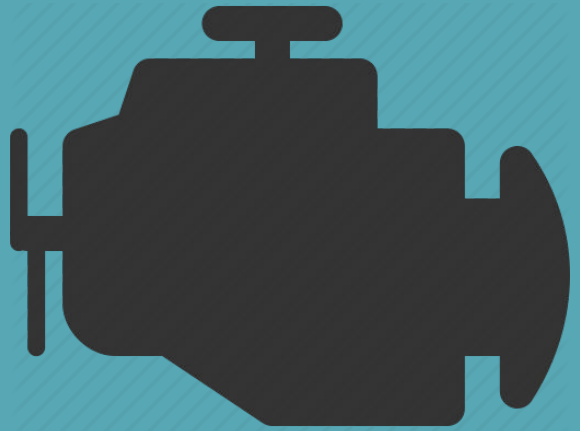


OUTPUTS

Go/No-Go
Color
Graphic
Torque
Shape
Size
Properties
Cure
Trim
Gloss

ADD AN **ENGINE** TO THE FUEL



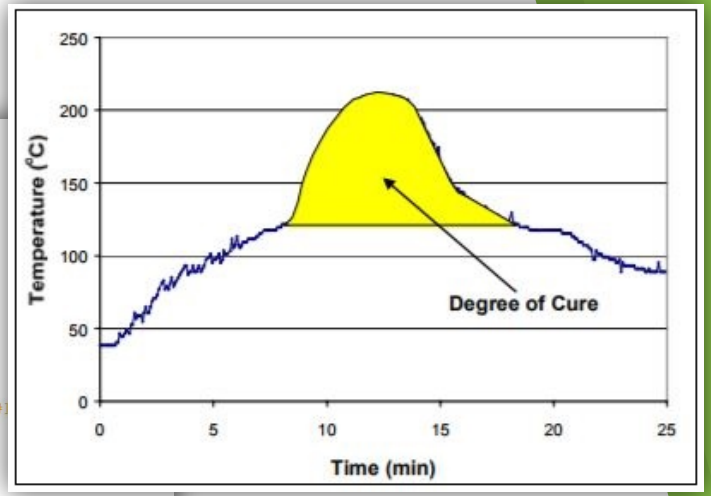


PROCESS OPTIMIZATION

Internal Temp Simulation and Process Optimization

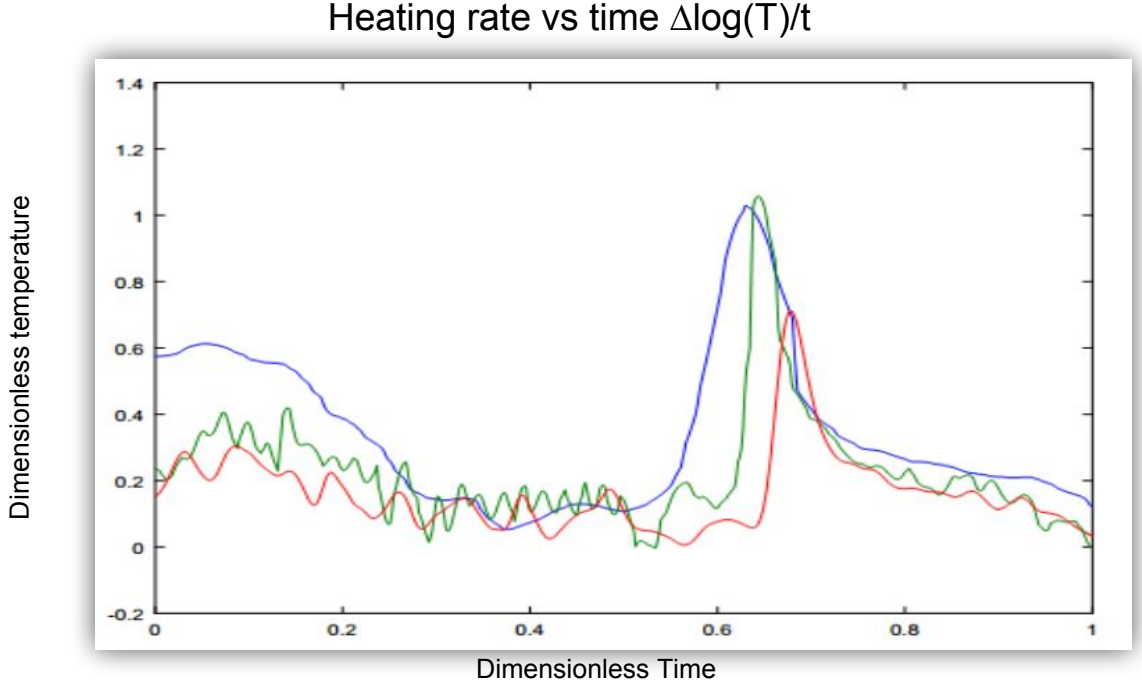
The Degree of Cure:
First stop in the journey

```
[FileName,PathName] = uigetfile({'*.xls;*.xlsx','Data Files (*.xls,*.xlsx)';'*.*','All Files (*.*)'}, ...
'Pick a File');

[FileName,PathName] = uigetfile({'*.xls;*.xlsx','Data Files (*.xls,*.xlsx)';'*.*','All Files (*.*)'}, ...
'Pick Another File',PathName);

A = [PathName,FileName];
sheet = input("choose worksheet:\t");
colrows = input("choose column and rows format example-- A2:A20:\t",'s');

m = xlsread(A,sheet,colrows);


##possible convection terms later
##grashof = (9.81 .* .00343 .* (100 .- 25) .* .0094488 .^3) ./ (.0000189 .^2);

WhichCol = input("Which columns are needed in array time first temp second --- format--- [xcolumn #, ycolumn #]

fill = m(:,WhichCol);

x = fill(:, 1);
y = fill(:, 2);

k = 1

while k != 0
{
k = input("press 1 to go 0 to stop");

D = input('choose derivative to use generally 3 ---');
Stddev = input('choose standard of deviation of data (2.1 - 3.9 usually accurate) ---');

[yhat,Lambda] = regdatasmooth(x, y, 'd', D, 'stdev', Stddev);
3
```

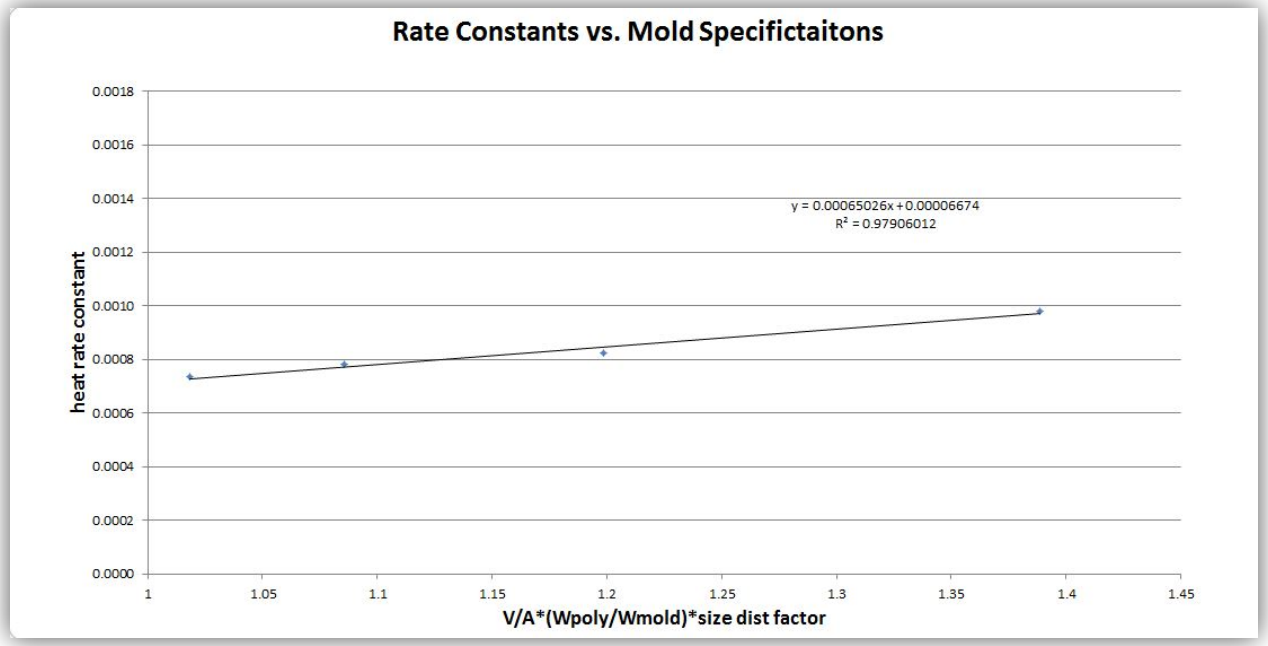


Heating Rates:

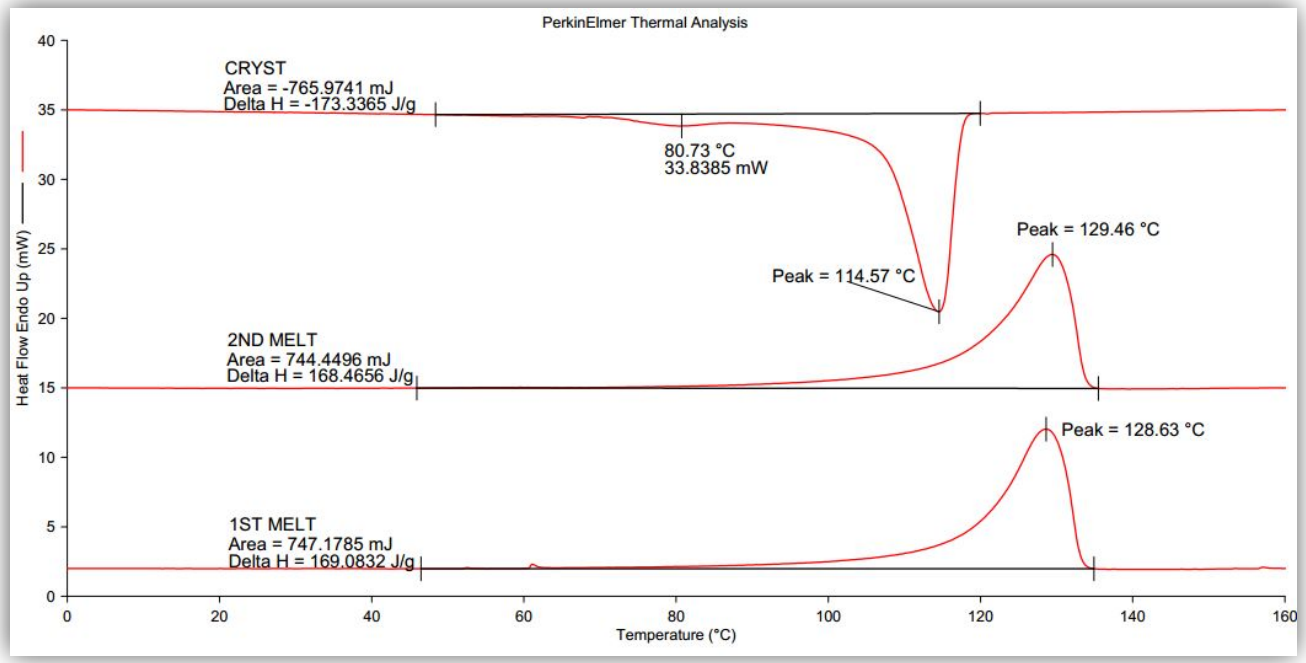
Rates of change give insight



Mold Specific Testing:
A Wealth of Knowledge



The DSC:
Using Differential Scanning Calorimetry to Quantify Melting



Fourier's Heat Equation:
Including Two Temperature Dependent Sources

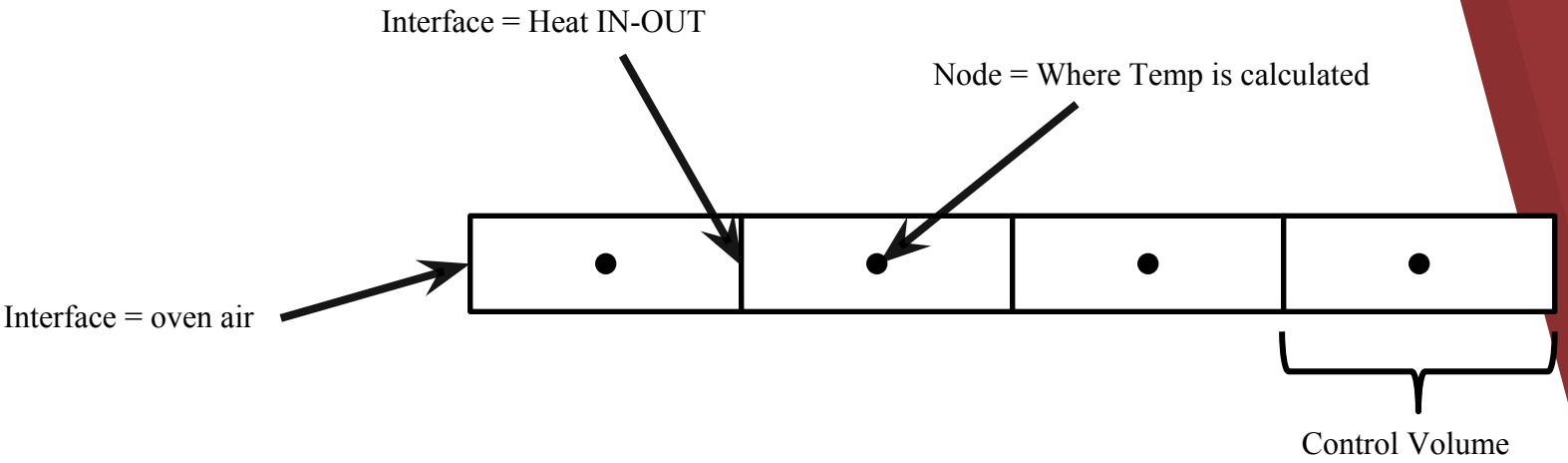
$$\frac{\partial T}{\partial x}\left(K(T,x)\frac{\partial T}{\partial x}\right) = \rho(x)C_p(x)\frac{\partial T}{\partial t} + \rho(x)H_m\frac{dX_m}{dt} - \rho(x)H_c\frac{dH_c}{dt}$$

IN-OUT ACCUM. CONS. GEN.

$T = Temperature$
$Cp = Specific\ heat$
$K = Conductivity$
$\rho = Density$
$H_m = Heat\ of\ melting$

$H_c = Heat\ of\ Crystalization$
$\frac{dX_m}{dt} = Melting\ Rate$
$\frac{dH_c}{dt} = Crystalization\ Rate$

Solving:
The Hard Part:
Control Volume Discretization



$$\begin{bmatrix} In + Acc. & -Out & 0 & 0 \\ -Out & In + Acc. & \ddots & \vdots \\ 0 & \ddots & \ddots & -Out \\ 0 & \dots & -Out & In + Acc \end{bmatrix}^{-1} \begin{bmatrix} T_1 \\ T_2 \\ \vdots \\ T_n \end{bmatrix} = T\ Sol'n$$

Solving:
The Hard Part: Differencing scheme

Series expansions for finite differencing

$$\left[u(t+\Delta t) = u(t) + \frac{du(t)}{dt}(\Delta t)\right] \ldots \frac{1}{2!}\frac{d^2u(t)}{dt^2}(\Delta t)^2$$

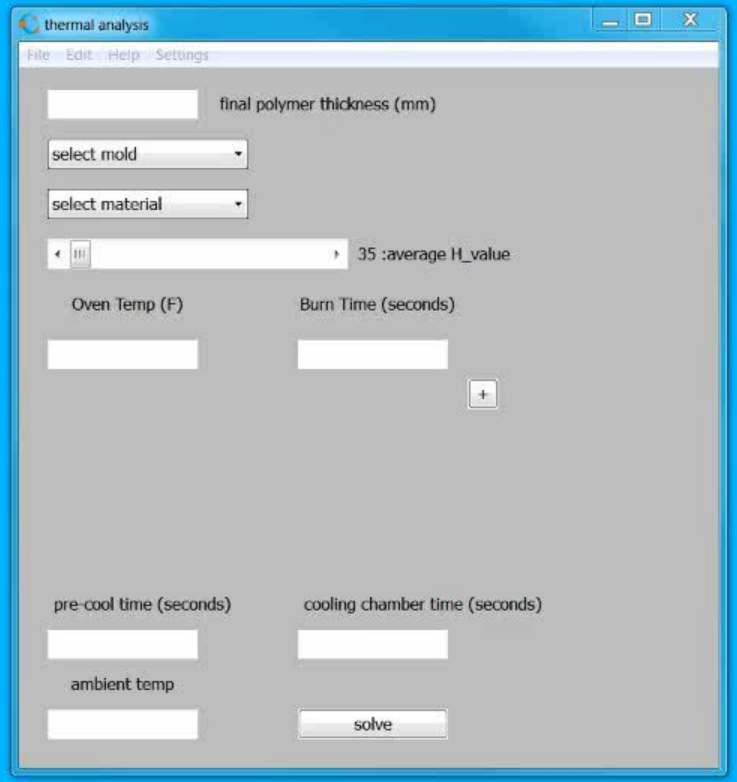
$$\frac{du(t)}{dt} = \frac{u(t+\Delta t) - u(t)}{\Delta t}$$

$$\left[u(x+\Delta x) = u(x) + \frac{du(x)}{dx}(\Delta x) + \frac{1}{2!}\frac{d^2u(x)}{dx^2}(\Delta x)^2\right] \quad \left[u(x-\Delta x) = u(x) - \frac{du(x)}{dx}(\Delta x) + \frac{1}{2!}\frac{d^2u(x)}{dx^2}(\Delta x)^2\right]$$

$$\frac{d^2u(x)}{dx^2} = \frac{u(x+\Delta x) - 2u(x) + u(x-\Delta x)}{2!\,(\Delta x)^2}$$

A DEMONSTRATION IS WORTH A THOUSAND WORDS

Let’s see it in action.


thermal analysis
File Edit Help Settings
final polymer thickness (mm)
select mold
select material
35 :average H_value
Oven Temp (F)
Burn Time (seconds)
+
pre-cool time (seconds)
cooling chamber time (seconds)
ambient temp
solve

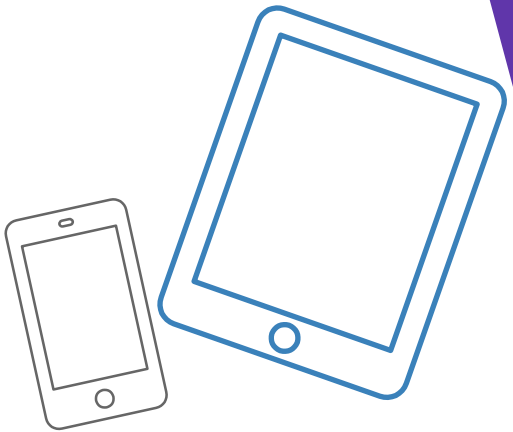
Think

97%
1:10 PM
9/21/2017


Brain Break

What's the **POINT**?

POTENTIAL USE IDEAS



THANK YOU!

Any questions?

You can reach me at dgrimes@centroinc.com

RECOGNITIONS
Steve Harkin and Mike Cairy – Centro Inc. R&D Techs who helped generate mountains of data to provide the “fuel”

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