Advances in 3E of Polymer Processing and Sustainable Manufacturing

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On behalf of

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Innovation Team of Polymer Processing Molding and Advanced Manufacturing
Outline

1. Challenges in Polymer Processing
2. Innovation on Sustainable Manufacturing
3. Conclusion and Future Work
1. Challenges in Polymer Processing
1. Challenges in Polymer Processing

Manufacturing Sci. & Tech. has 4 research fields:

- Inorganic no metal Manufacturing
- Organic Polymer Manufacturing
- Metal Manufacturing
- Composites Manufacturing
1. Challenges in Polymer Processing

My Research Team focus on Polymer Processing

- Organic Polymer Manufacturing
- Inorganic no metal Manufacturing
- Metal Manufacturing
- Resin Matrix Composites Manufacturing
1. Challenges in Polymer Processing

Polymer Processing

Resin → Products

Pre-Processing
- Drying
- Mixing
- Blending
- ...

Molding
- Extrusion
- Injection
- Rotational
- Composite
- ...

Post-Processing
- Vulcanization
- Cross-linking
- Joining
- ...

There are 3 steps in Polymer processing from resin to products
2. Innovation on Sustainable Manufacturing

3E: Efficiency, Energy-saving, Environment-friendly
2. Innovation on Sustainable Manufacturing

3E: Efficiency, Energy-saving, Environment-friendly
2. Innovation on Sustainable Manufacturing

3E: Efficiency, Energy-saving, Environment-friendly

Near net shape forming technology is in dominant position of polymer processing.

Injection Molding is a good example.
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Problems

Injection Molding

What’s the filling behavior and Why in the “black box” mold
How to discover it so as to make nice products

Visualization experimental installation

1) Filling Process

Performance & Shape

成性 + 成形

2) Internal Stresses

Simulation

Test Sample
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Problems

Shrinking and Warping

Injection Molding

Discover the Deformation laws of polymer molding is important & difficult

3) Deformation Laws

How

Precision Control

\[ V(T, P) = V_0(T) \left\{ 1 - C \ln \left[ 1 + \frac{P}{B(T)} \right] \right\} + V_1(T, P) \]

P Pressure
V Volume
T Temperature

Nonlinear PVT properties
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Key Problem

How to control the molding precision?

The only answer is,
By PVT Properties
But not by calipers

Polymer Molding (3D copying)

PVT

Metal Cutting

Polymer Rapid Prototype (3D printing)

如何控制精度？
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Key Problem  How can we get PVT property?

\[ V(T, P) = V_0(T) \left\{ 1 - C \ln \left[ 1 + \frac{P}{B(T)} \right] \right\} + V_1(T, P). \]

USA Gnomix

Germany SWO

Japan Toyo Seikei
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Research

We invented a PVT tester

Patent: ZL200710063461.3

Please pay attention to the difference of the PVT Test Mechanism

Amplified factor = 20

China BUCT

Amplified factor = 0

USA, Germany, Japan
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Result and Application

It was applied in China Haitian’s IMM, and result in high precision level.

Haitian Group Ltd.

Injection Molding Machine Precision Level 0.037%
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Result and Application

USA PLASTICS NEWS said: Haitian overtakes global giants
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Problems

There exists Material and Energy Waste

In molding micro parts for 3C products, more than 90% materials will be recycled for many times, or molding it by many micro Injection Molding Machines.
We studied the **imbalance flow behavior**, and understand that it’s due to the asymmetric shearing heat distribution.
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Result and Application
We proposed a New Concept: Melt Differential Theory for polymer processing
And then invented Differential Injection Molding

Patent: ZL200810227241.4

Hot Runner of Differential Pump
Energy & Mater. Waste = 0
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Result and Application

We also invented Melt Differential Extrusion Molding Method

China Patent: ZL200910237622.5

USA Patent: 3557265

Meta Materials

超材料

100-1000 layer, Nano-structure
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Result and Application

Obviously, flow easily result in Energy-saving

China BUCT

USA

Different

Result

Micro layer Structure

Mechanism
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**Problems**  Energy Waste Rubber Industry

Tire vulcanization heating by water vapor. The inside rubber mold is badly poor in heat transfer.

![Tire mold](image)
- Outside (steel)
- Inside (rubber)

Tire vulcanization machines
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Problems Energy Waste Rubber Industry

Huge tire vulcanization heating time is long to 10 hours. Energy-saving method is very important.
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**3E:** Efficiency, Energy-saving, Environment-friendly

**Research** We developed efficient heat transfer method, and invented a new vulcanization equipment.

- Rubber mold
- Steel mold
- Water vapor
- Electromagnetic
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Result and Application
Performance increased & Energy saving 8~10% !

Outside surface
Inside surface
X-ray Test result
Temperature test points

Temperature curve
Molding precision (Tolerance)
High speed test
Durability test
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3E: Efficiency, Energy-saving, Environment-friendly
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Problems PM2.5 Pollution need Micro and nano-fiber
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Problems

The best way to make nano-fiber is Electro-spinning

Prof. Reneker in USA, has greatly promoted Polymer solution electro-spinning technology.
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Problems

In 2010 Shanghai World Expo Czech put forward nano spider

Polymer solution electro-spinning

3 Shortages:

- Low strength of fiber. Defects caused by solvent evaporation
- Low productivity. < 5% of the solution become fibers
- Solvent pollution. PP, PE cannot find solvent
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Research

Progress in Melt Electro-spinning

Books & papers published during the past 10 years:

Only 1% of the published papers is about Melt-Electro-Spinning.

We started this research from 2005, and find it was limited by method and equipments.
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Research

Then we invented Melt Differential Electro-spinning Method

As you know, Capillary electro-spinning is like a water tap:

Polymer Solution Electro-spinning

Melt Differential Electro-spinning

No Solvent pollution
Energy saving
High efficiency

Inspiration from nature waterfall
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**Result and Application**

We are doing very interesting work, and got lot of superfine fibers shown as the upside pictures, it is colorful because the diameter is as small as light wavelength.
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Result and Application

Up to now, we hold 14 Patents published 23 papers.

Our new theory explaining the mechanism of Melt electro-spinning:

Melt Differential

Tug of war effect

New technology: Production Line
3E: Efficiency, Energy-saving, Environment-friendly

Big Problem
Finally, I have to remind a very serious problem in polymer industry—Mercury Pollution. China is the largest country in mercury consumption, 59% used in PVC producing.

China Mercury Consumption Map

Hg Pollution

isci (see the figure). The use of stable isotopes of mercury has improved scientists’ ability to trace pathway (7, 8)

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2. Innovation on Sustainable Manufacturing

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In order to solve the Oil dependence and mercury pollution in Polymer Chemical industry, We invented an Eco-method from Stone to Polymer

Stone

China

Hg?

World

Oil?

Patents: 201310300933.8

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3. Conclusion and future work
Advances in Sustainable Manufacturing of Polymer Processing

3. Conclusion

1. Developed: Scientific instruments and equipments

- Visualization equipment of polymer injection molding
- PVT test equipment of polymer processing
- Polymer Melt Electro-spinning equipment

Important discovery and know how to do better

- Filling balance related with Shearing heat distribution
- PVT properties depend on Shearing rate/T & P gradient
- Polymer Melt Differential Law and Tug of War in ES
3. Conclusion

2. Invented and developed some 3E method and machines

- Efficient micro injection molding
- Energy saving Extrusion molding
- Energy saving radial tire manufacturing
- Environmental friendly Melt ES
3. Future work

Mechanical + Chemical = Environmental friendly organic materials
3. Future work

Develop PVT tester for Ultra-high speed and precision polymer molding and 3D printing

Mechanical + Chemical: Solve important scientific and technical problems
3. Future work

Develop PVT tester for Ultra-high speed and precision polymer molding and 3D printing
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