SolutionPartner

Troubleshooting_Extrusion

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Contents

Preparation for Troubleshooting

- Acquiring the process data
  - Measuring process variables : Be sure to check and record every data because it acts like a black box
  - Set temp. and current temp. of barrel (cylinder), and die
  - Resin temperature(℃)
  - Resin pressure(bar)
  - Motor torque(A, %)

- Acquire extrusion theories and case studies

- Analyze past processing data, and compare it with the current one
  - Compare the process variables in the past (which was in normal state) with the current one
    ① Process information ← Measured process variables
    ② Reliability of the measured data ← Checking whether various sensors and heaters are malfuntioning
    ③ Information of the screw dimensions ← Checking whether it is worn out or not
    ④ Information of the resin in use ← Check rheological, thermal, and mechanical properties

- Collaboration between production/quality/purchasing/equipment team members

5-Step Troubleshooting

- 1-Step : Understanding the problem
  - List the possible causes, review the process conditions of a normal state, comparing with the past/ present phenomenon
    - ① Uneven supply of a raw material
    - ② Improper extruder temp. setting and melt temp. of a resin
    - ③ Improper drying or cooling
    - ④ Contaminants
    - ⑤ Improper puller (or haul-off) speed

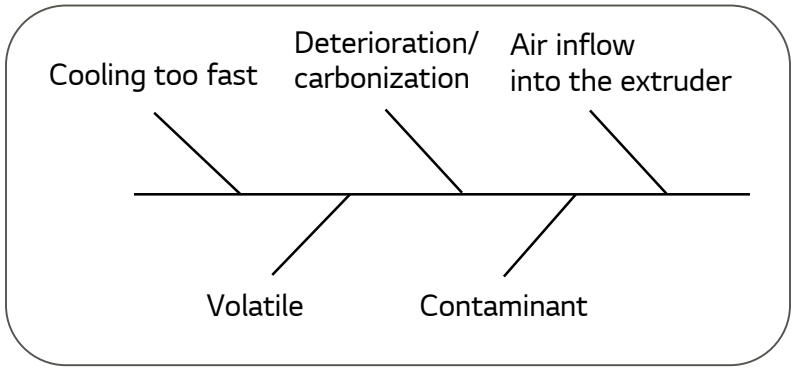
- 2-Step : Resolving the problems
  - Although it is not a permanent solution, immediate action is required to resolve the underlying problem.

- 3-Step : Identifying essential causes
  - Basic inspection of process quality management 5M + 1E
    - ① Man : Whether or not the operator is working improperly
    - ② Machine : Whether the machine/structure is broken or not
    - ③ Measurement : Check process conditions, whether the physical properties of final product is measured properly
    - ④ Material : Check whether the content of stabilizers and additives are adequate, and blending procedure is OK
    - ⑤ Method : Whether the correct process conditions are fulfilled
    - ⑥ Environment : Check if there are inadequate working environment such as temperature/humidity/contaminant

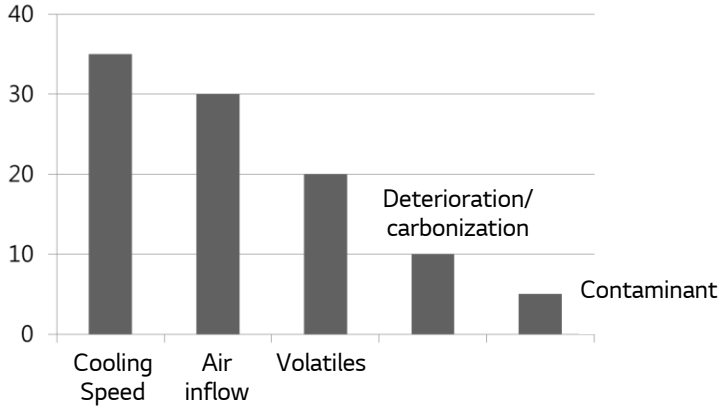
5-Step Troubleshooting

- If needed, use brainstorming, fishbone diagrams, pareto analysis etc. to identify one or more hidden causes

Fishbone diagram : Reasons for voids



Pareto diagram : Reasons for voids



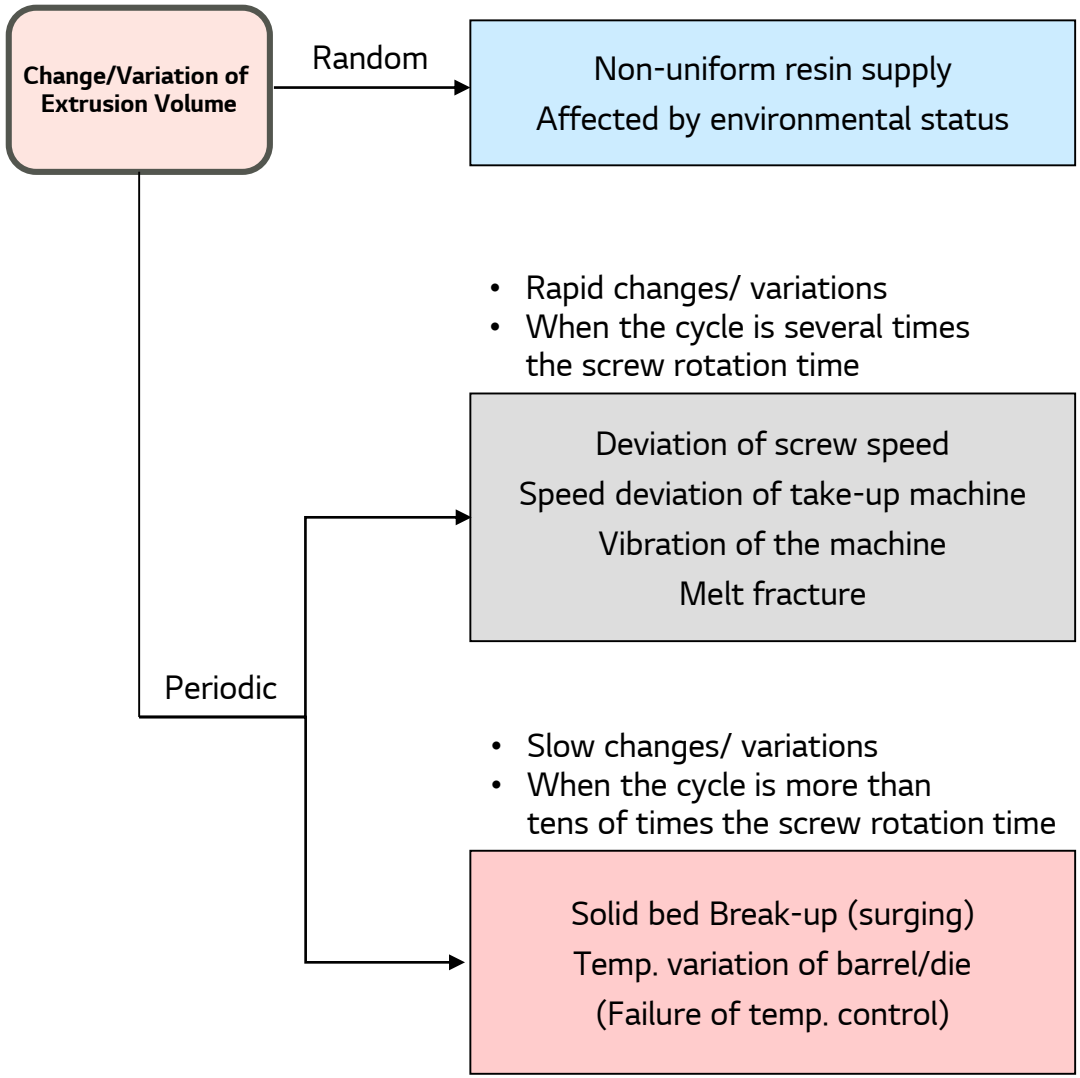
4-Step : Actions

- Providing optimal solutions through communication with customers
  - ① Minimize cost
  - ② Minimize time spending
  - ③ Guarantee reliability
- Improvement of product's color, physical properties, size, surface quality, etc.

5-Step : Final process monitoring

- After corrective action, final monitoring is required to ensure that the problem has been resolved properly and has not recurred.

Change/Variation of Extrusion Volume



- Keeping constant level of resin in the hopper
- Check the room temp. and humidity
- Check the voltage deviation in the factory

- Introduce real-time data measurement device
- Check alignment of screw, gearbox and motor
- Reduced shear stress of die land
  - Increase die setting temp.
  - Widen the die gap
  - Reduce extrusion volume

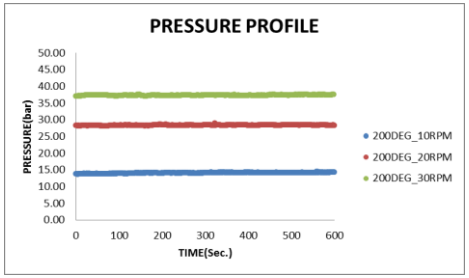
- Optimize screw design
  - Adjust screw compression ratio
  - Increase screw compression length
  - Introduce&use screw cooling system
- Check barrel/die temperature control

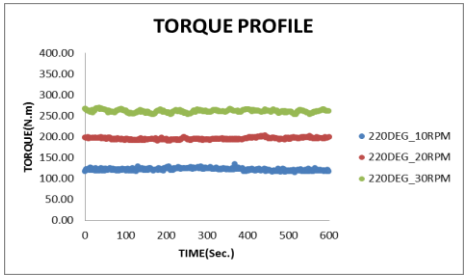
Pressure and Torque Fluctuations

Pressure and torque fluctuations

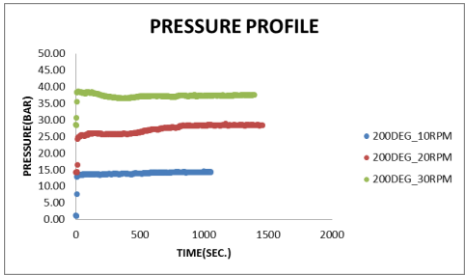
- Insufficient Mixing → Use pre-mixer etc. for Sufficient Mixing
- Screen pack Contamination
- Old adapter and die heater → Replace the heaters and fix them tightly
- Barrel temp. fluctuation → Check if temp. control works properly

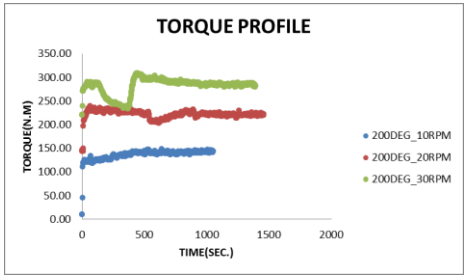
Stable extrusion





Unstable extrusion





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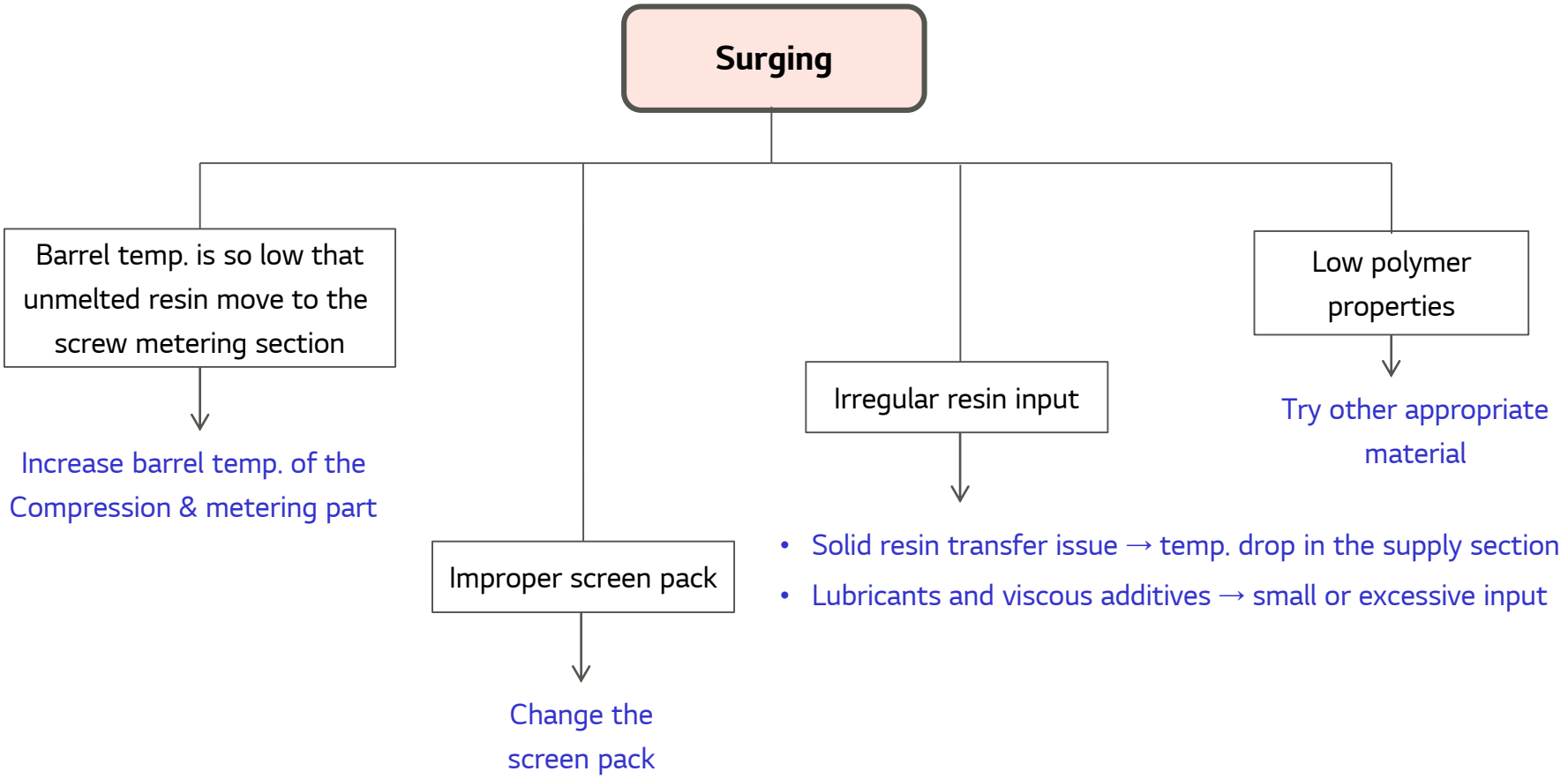
Surging

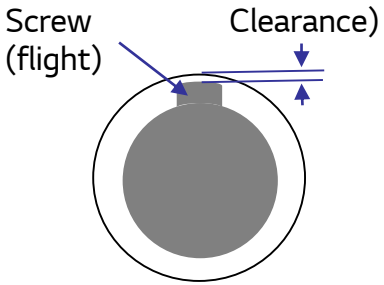
- Surging : A phenomenon which extrusion volume is not constant and shakes



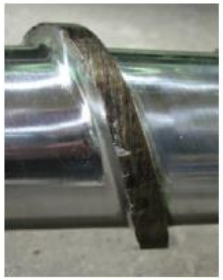
Screw Wear-out

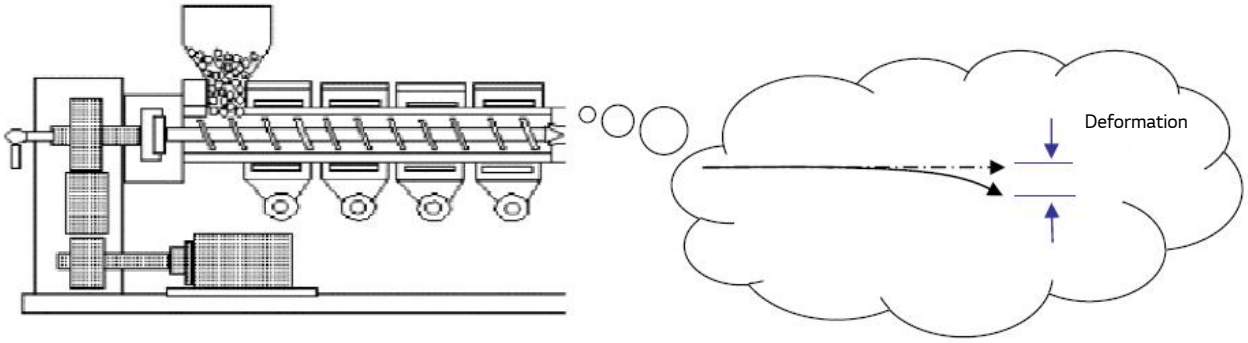
- Clearance increase due to screw wear out
  - Inevitable deformation of the screw → Contact with the barrel surface when rotating → Screw flight wear out
  - Reduces productivity (Fluctuate decrease or deviation) or reduces extrusion uniformity (increased temp. deviation)

  → Screw should be regularly managed

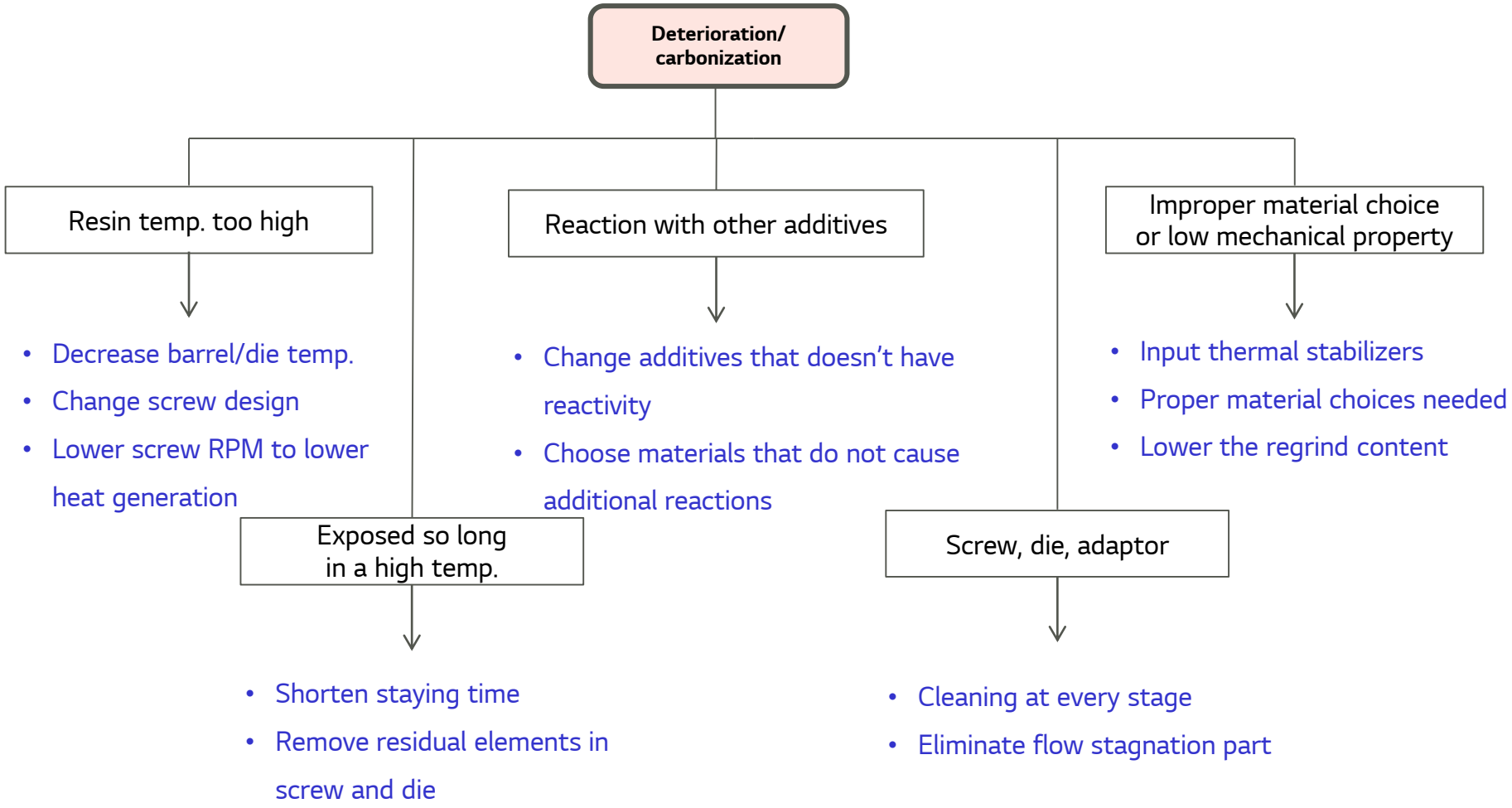


Cross-section of screw





Deterioration/Carbonization



High Resin Temp. & High Motor Torque

- High resin temperature
  - Screw design aspect
    - ① Relationship between channel depth and RPM : Viscous heat
    - ② Excessive or inadequate dispersion of mixing element (Maddock, Egan etc.)
  - Processing aspect
    - ① Check barrel temp. control unit
    - ② Check barrel cooling unit
    - ③ Die pressure reduction

Standard Maddock screw : Local overheating is possible

Upgraded screw : Suppress local overheating

- High motor torque
  - Check list
    - ① Whether the screw design is suitable for the resin
    - ② Whether the length of the extruder (screw) is appropriate to the resin
    - ③ Whether the current processing conditions are appropriate compared to the previous one
    - ④ Whether the barrel and die heaters are working properly
    - ⑤ Possibility of resin retention inside the extruder

Deformation of the Product

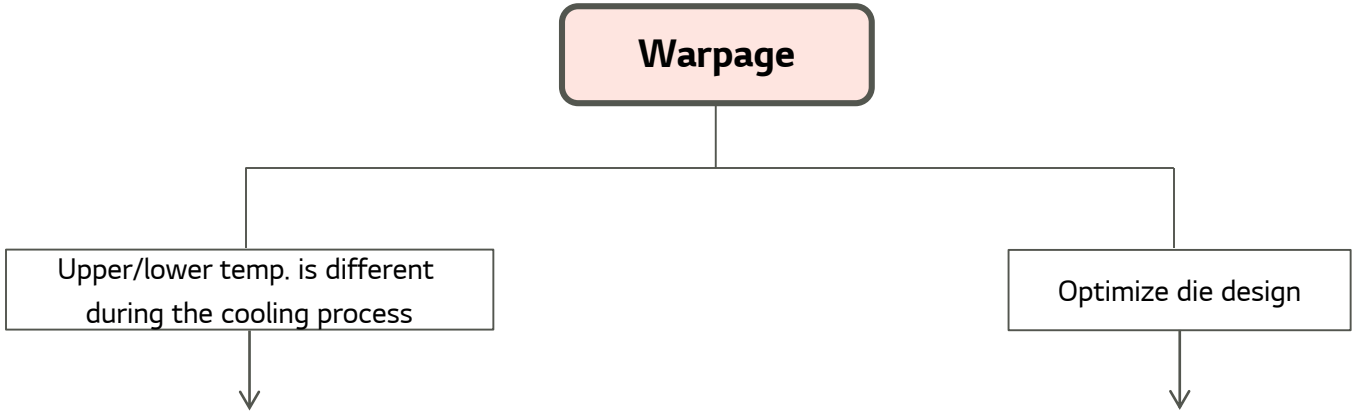
Random deformation

- Differences in physical properties of raw materials
  - Check raw material mechanical property (lot by lot)
    ex) molecular weight, viscosity
- Complex problem of screw RPM, Pressure, and barrel temp. etc
  - All process condition need to be monitored
  - Collect torque pressure data

Deformation over time

- External energy input changing according to the time
  - Check whether the melt temperature and pressure of the resin are constant
  - Make sure the extruder's temperature control is working properly
  - Check external environmentail factors
    ex) Inflow of clod air and temp. of pellet
- Change of molecular weight
  - Check raw material's molecular weight by manufacturing date

Warpage

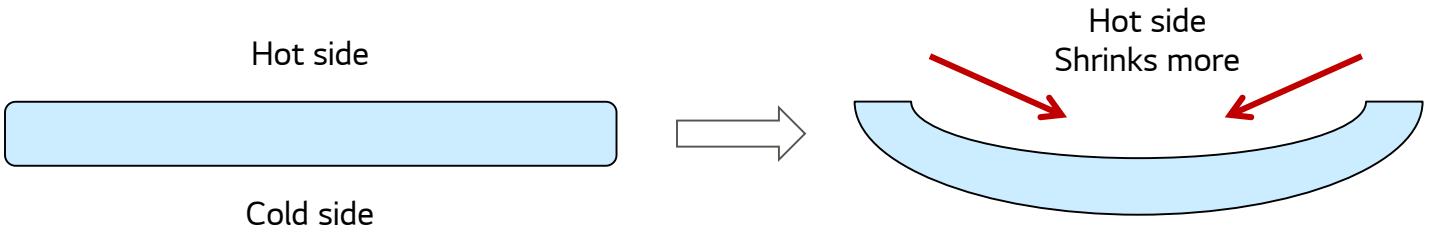


Take measures so that it can solidify equally through temp. control

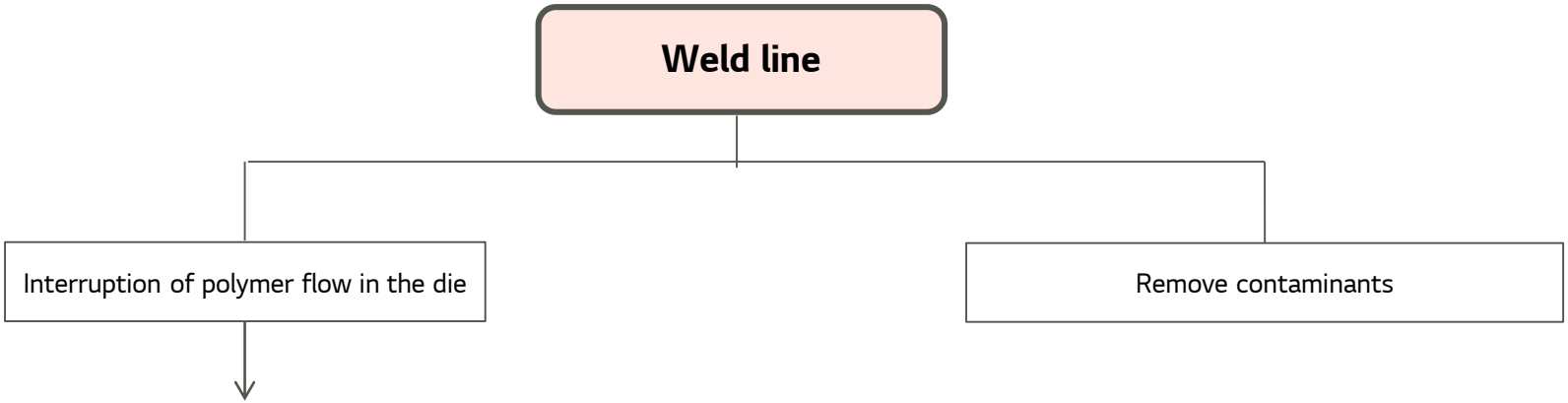
- Adjust die land
- Adjust product's cross-sectional dimension

ex) If thick part cools slowly compared to the thin part

- Shrinkage and warpage with regard to cooling rate

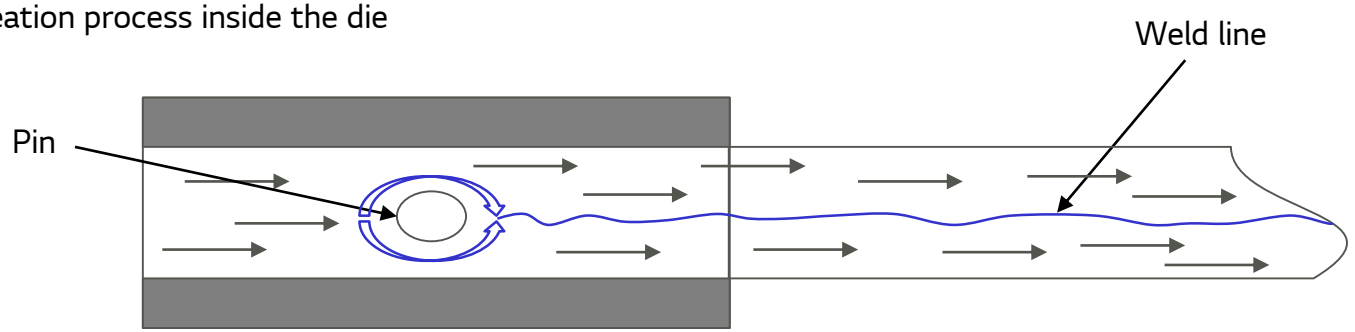


Weld line

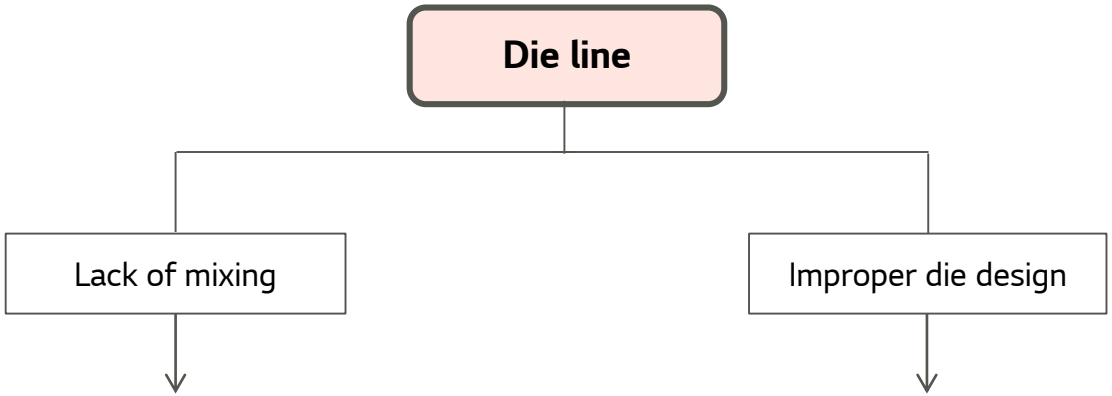


- Increase entanglement in molecules
  : Increase barrel temp., pressure, or die temp.
- Increase die length to provide sufficient flow to increase intramolecular entanglement
- Change die design for resin to be mixed after polymer flow is recombined

▪ Weld line creation process inside the die

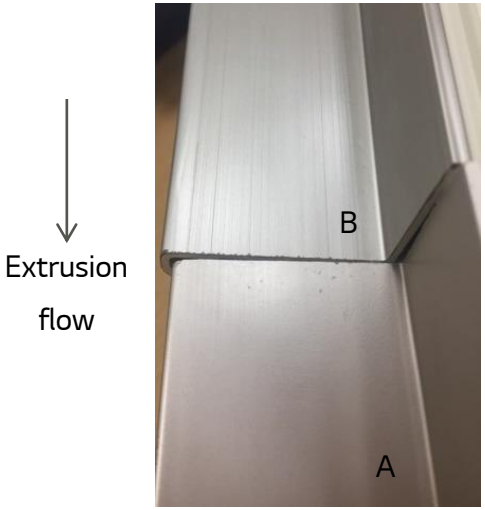


Die line



- Change mixing screw (ex. Maddock)
- Increase barrel temp increase mixing efficiency

- Problem of die fastening
- Scratch on the die flow path
- Resin stagnation inside or at the exit of the die
- Die design defect



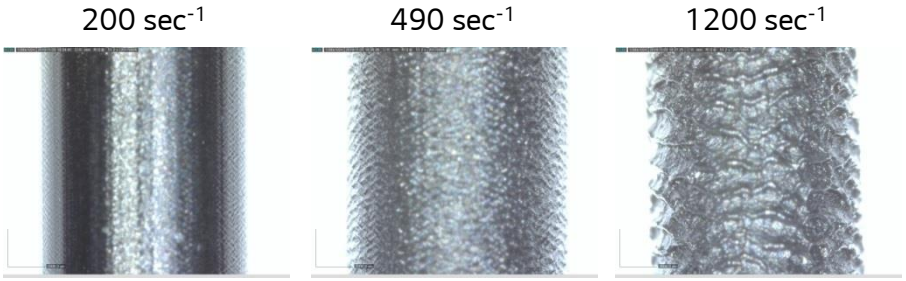
Die line

Melt Fracture

Melt Fracture

- Increase temp.
  - Method : Die & Screw metering section temp increase
  - Characteristics : Internal die stress decrease
  - Limits : Reduced resin shape retention, color change, carbonization
- Change die structure
  - Method : Increase die land
  - Characteristics : Securing sufficient stress relief time inside the die
  - Limits : Pressure increase, facility space constraints, new investment costs, etc.
- External lubricant
  - Method : Addition of lubricants such as PPA* or wax etc.
  - Characteristics : Reduces stress by inducing slip on the die surface
  - Limits : Affects physical properties, might not have expected effects etc.
- High MI material

*PPA : Polymer Processing Aid



<Image of Melt fracture according to Shear stress>

Bubbles

Bubbles

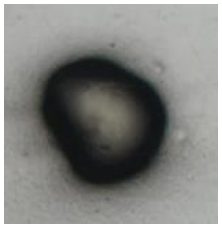
- Air inflow into the extruder
  - Use vent ports
- Contaminants inside the resin
  - Sufficient pausing is a must, in order to remove substances such as residual resin, additives, etc.
- Fast cooling speed
- Moistures
  - Drying is necessary
  - Use vent ports

Gel

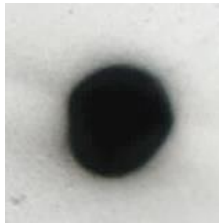
Gel

- **Long time exposure to high temp.**
  - Eliminate stagnation part in the extruder
    - : Stagnating in the mixing part
    - : Screw, die, barrel surface defects
  - Reduce stay time
- **Crosslinking in the die**
  - Optimize screw design
- **Gel vs Unmelt**
  - Use hot-stage microscopy or heat to determine non-fusion
- **High molecular weight materials**
  - Filtering by increasing the no. of screen pack mesh
  - Increase melt temp. to prevent clumping
- **Contaminants**
  - Remove possibility of contamination

▪ Microscope image by gel type

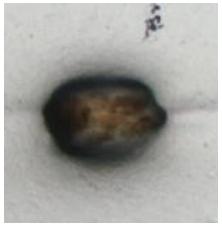


Typical spherical shape



Carbide

Contaminants (atypical dust, fibers)



Colored contaminant

Drool

- Die drool : Accumulation of material on the outer side of the die

Drool

Influence by ingredients with insufficient compatibility

- Remove inappropriate ingredients
- Add compatibilizer

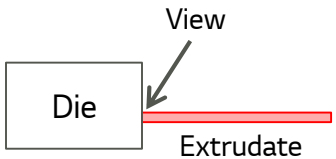
The difference between the material of the die and the surface energy of the polymer

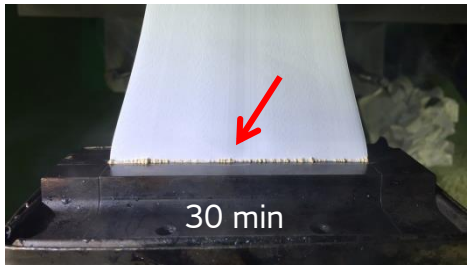
- Method : Die surface coating (Fluoropolymers)
- Characteristics : Decrease of surface energy between die and polymer
- Limits : Coating peeling off, one-time usage

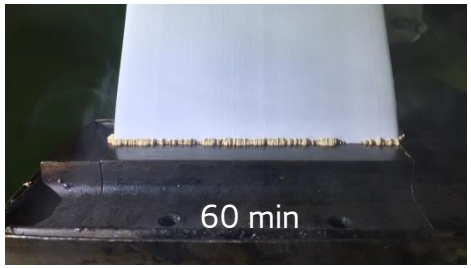
Stress from die

- Optimizing die set temp.
- Optimizing die design

- Die drool change according to sheet extrusion time







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