Simulation of plastic injection for nano roughness replication

Barcelona, 14th April 2016

J.Pina-Estany¹, J.Fraxedas³, F.Perez-Murano³, C.Colominas², J.M.Puigoriol-Forcada¹, A.A.Garcia-Granada¹

¹IQS-Universitat Ramon Llull; ²Flubetech SL; ³ICN2-CNM-CSIC Barcelona;

Contact: jordi@pina.cat, Via Augusta 390, E08017, Barcelona, Spain.
Overview

1. Introduction to aim4np project
2. Simulations of plastic injection at nano level
3. Experiments of plastic injection at nano level
1.- Introduction to aim4np project

Aim4np is a FP7 funded project to build an Automated In-line Metrology for (4) Nanoscale Production.

http://aim4np.eu/
Measurement of nanomechanical properties for:

- Quality control
- Tool-lifetime monitoring
- Maintaining precision
- Processing control

Crucial for an efficient production!

1.- Introduction to aim4np project

Production enters nanometer domain

image: www.icsana.com

image: www.syntecoptics.com

aim4np
1.- Introduction to aim4np project

Challenge

Environmental vibrations hinder the stable proximity needed for conducting nanomechanical measurements!

Possible implementation of probes:
- Atomic Force Microscope [AFM]
- White Light Interferometer [WLI]
1.- Introduction to aim4np project

Proposed solution

- Robot
- Actuator frame
- Controller
- Sensor
- WLI (White Light Interferometer)
- AFM (Atomic Force Microscope)
- Sample

Vibrations

fast, flexible placement on free-form work pieces

AFM...Atomic Force Microscope
WLI...White Light Interferometer
MP ... Metrology Platform
Plastic injection application of aim4np

Plastic injection is selected as a possible application for aim4np to control moulds and plastic parts in-line to assure surface quality.

- Flubetech provides DLC coatings ranging $S_q=6$ to $35\text{nm}$.
- CSIC-CNM measure coating on mould $S_q=6\text{nm}$, and plastic parts from $4\text{nm}$ to $0.6\text{nm}$.
- IQS carries out simulations of plastic injection.
- External partner plastic injection.
2.- Simulations of plastic injection at nano level

2.1. Model to validate

2.2. Approaches

2.3. Submodeling approach

2.4. Results

2.5. Roughness applied
2.- Simulations of plastic injection at nano level

2.1 Model to validate

How does the polymer fill a nanomark? A first intuition could be…
2. Simulations of plastic injection at nano level

2.2 Approaches

**Option 1:** Mesh all the mesh at the nanoscale.
Computationally unaffordable. ✗

**Option 2:** Simulate both size scales in one simulation.
Unphysical results [1, 2] ✗

Air trap is detected on nano pools,
but also on fine mesh with flat surface

2. Simulations of plastic injection at nano level

2.3 Submodeling approach

Macro simulation

Nano simulation

Polymer inlet

Boundary conditions

1500nm
2.- Simulations of plastic injection at nano level

2.3 Submodeling approach

**Part 1:** The polymer goes through the nanomark

![Diagram of polymer injection](image)

Nanometer size (aprox. 2000nm) 
$t=0.00015s$
2.- Simulations of plastic injection at nano level

2.3 Submodeling approach

Part 2: The polymer moves into the nanomark until solidification

Atmospheric pressure outlet

Steel Wall at 335K. Slip condition

Polymer

Simmetry

Pressure inlet UDF: Submodeling of macro simulation
2. Simulations of plastic injection at nano level

2.4 Results
2.- Simulations of plastic injection at nano level

2.4 Results

Simulation

Experimental result
Surface A and surface B have the same roughness...

![Diagram showing surface A and B with roughness profiles]

\[ Ra = 0.5 \times d \]

But surface A roughness is replicated easier than surface B.
2.- Simulations of plastic injection at nano level
2.5 Roughness applied

Ra plastic part vs. Ra mould

- Perfect replication
- L=457nm serie
- L=914nm serie

D=185nm
D=370nm
D=93nm
2.- Simulations of plastic injection at nano level
2.5 Roughness applied

Evolution of roughness with time
3.- Experiments of plastic injection at nano level

MOULD
Roughness
Micro pattern
Nano pattern

PLASTIC PART
Roughness?
Micro pattern?
Nano pattern?
3. Experiments of plastic injection at nano level

SEM images of the mould nano pools:

G1. 4x20um

P1: 4x20um

AFM image of the plastic part:
3.- Experiments of plastic injection at nano level

AFM image of the plastic part
3.- Experiments of plastic injection at nano level
4.- Storage of material properties

We need the creation of a database to store material properties used along this project for current polymers and mould conditions.

Such place should be driven by https://emmc.info/
Thank you

4nm \( \uparrow \) 2016nm