Application of Stress Wave Analysis in Multi-Layer Coating Design

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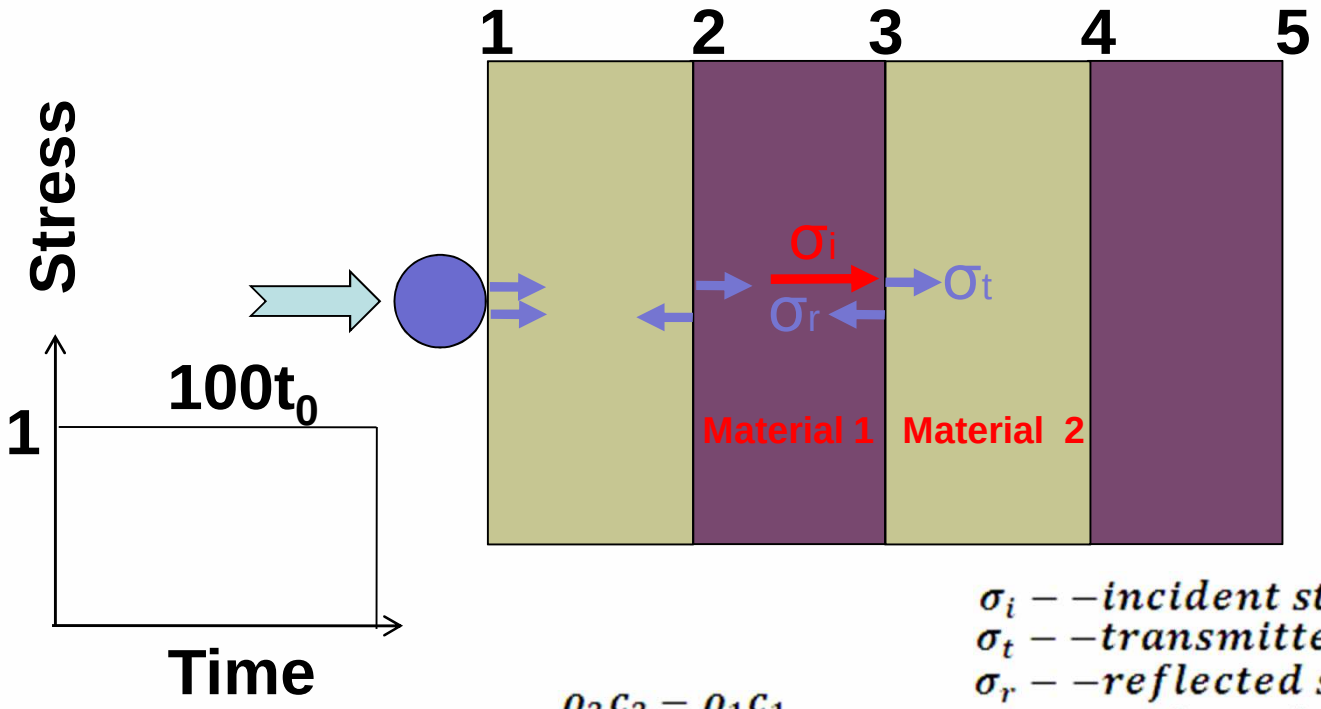
OUTLINE

1. Theoretical Background & Simplifications
2. Calculated Results
3. Conclusions

1 Theoretical Background & Simplifications

Background: Simplifications

Interfaces:



$$\sigma_r = \frac{\rho_2 c_2 - \rho_1 c_1}{\rho_2 c_2 + \rho_1 c_1} \cdot \sigma_i$$

$$\sigma_t = \frac{2\rho_2 c_2}{\rho_2 c_2 + \rho_1 c_1} \cdot \sigma_i$$

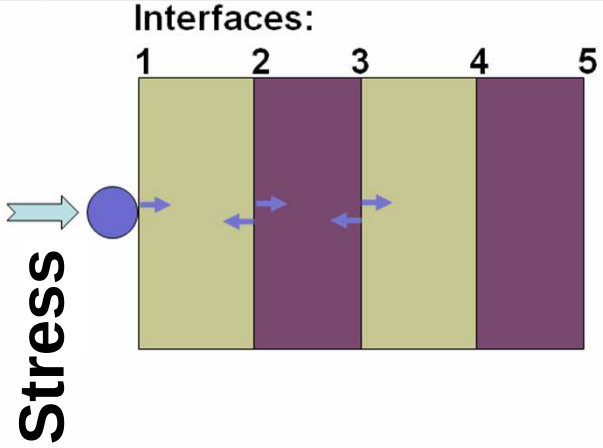
σ_i – –*incident stress*
σ_t – –*transmitted stress*
σ_r – –*reflected stress*
ρ – –*medium density*
c – –*wave speed in medium*

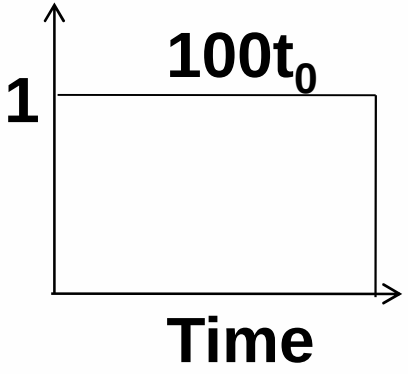
$$c = \sqrt{\frac{E}{\rho}}$$

E — *Young's modulus*

Ref 3: Li, 2003.

Background: Simplifications



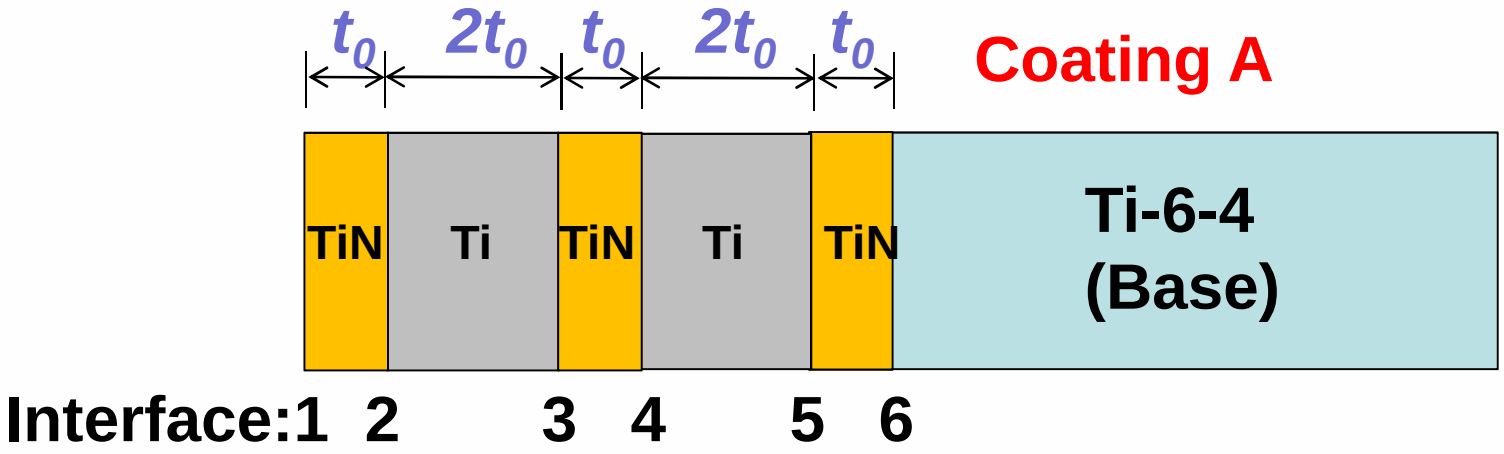


Simplifications:

1. **Single droplet**
   (Φ16.65 μm, 500m/s)
2. **Linear and rectangle wave**
3. **Incident stress = 1 unit**
4. **Incident time range = $100t_0$**
   (t_0=3.3E-10 s)
5. **100 pulses**
6. **<u>No energy loss</u>**
7. **Thickness design** (t_0 by integer)
   $1t_0$------3.5 μm TiN / 1.6 μm Ti layer

Coating A

Time the wave travel through each layer



Simplifications:

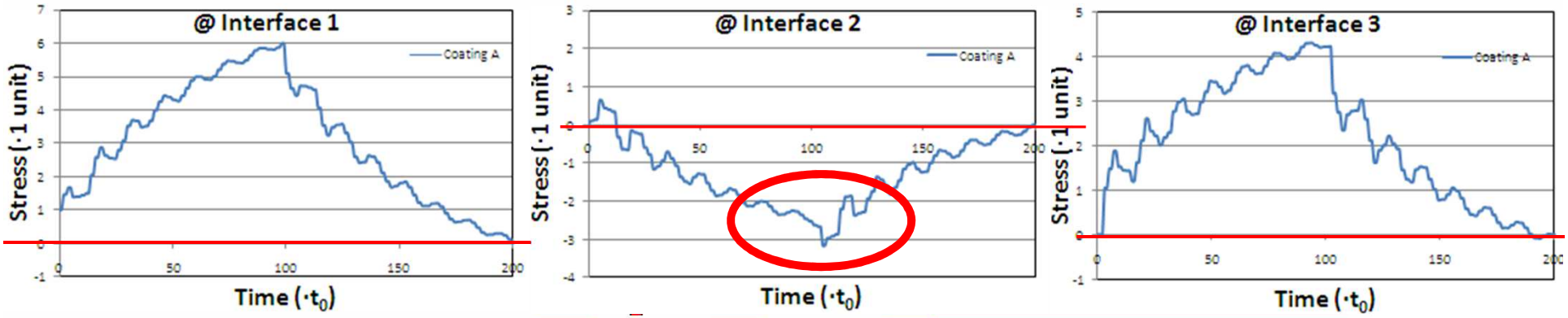
8. Base metal thickness: infinite

2 Calculated Results

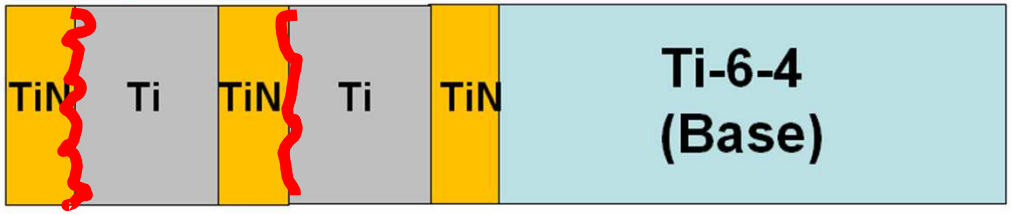
2

Calculated Results

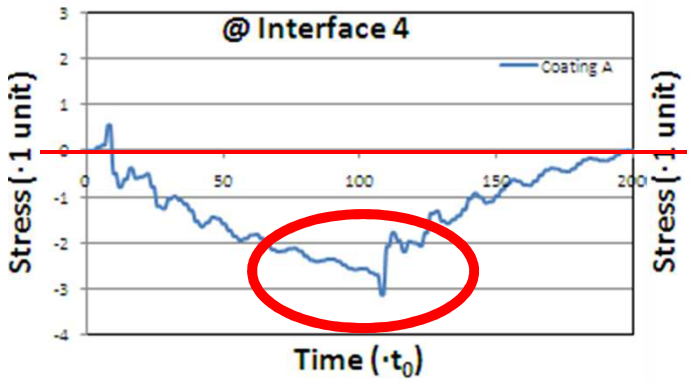
Coating A: Incident Compress. → tensile @ 2, 4 interface

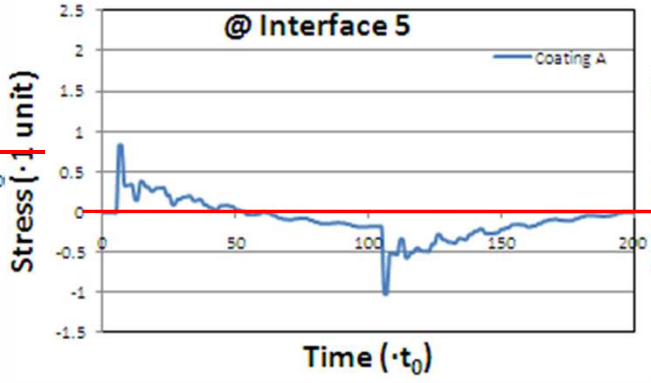


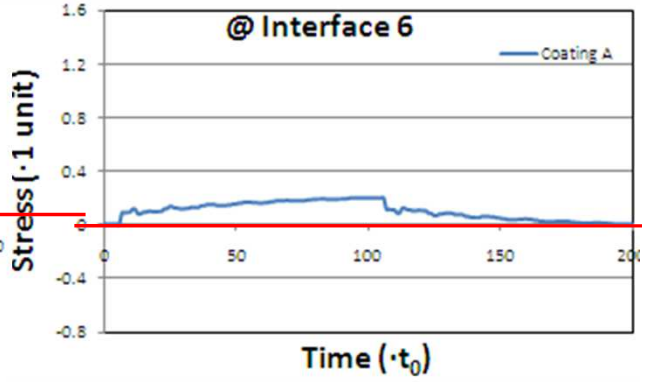
Potential fatigue crack initiation site



Interface:1 2 3 4 5 6

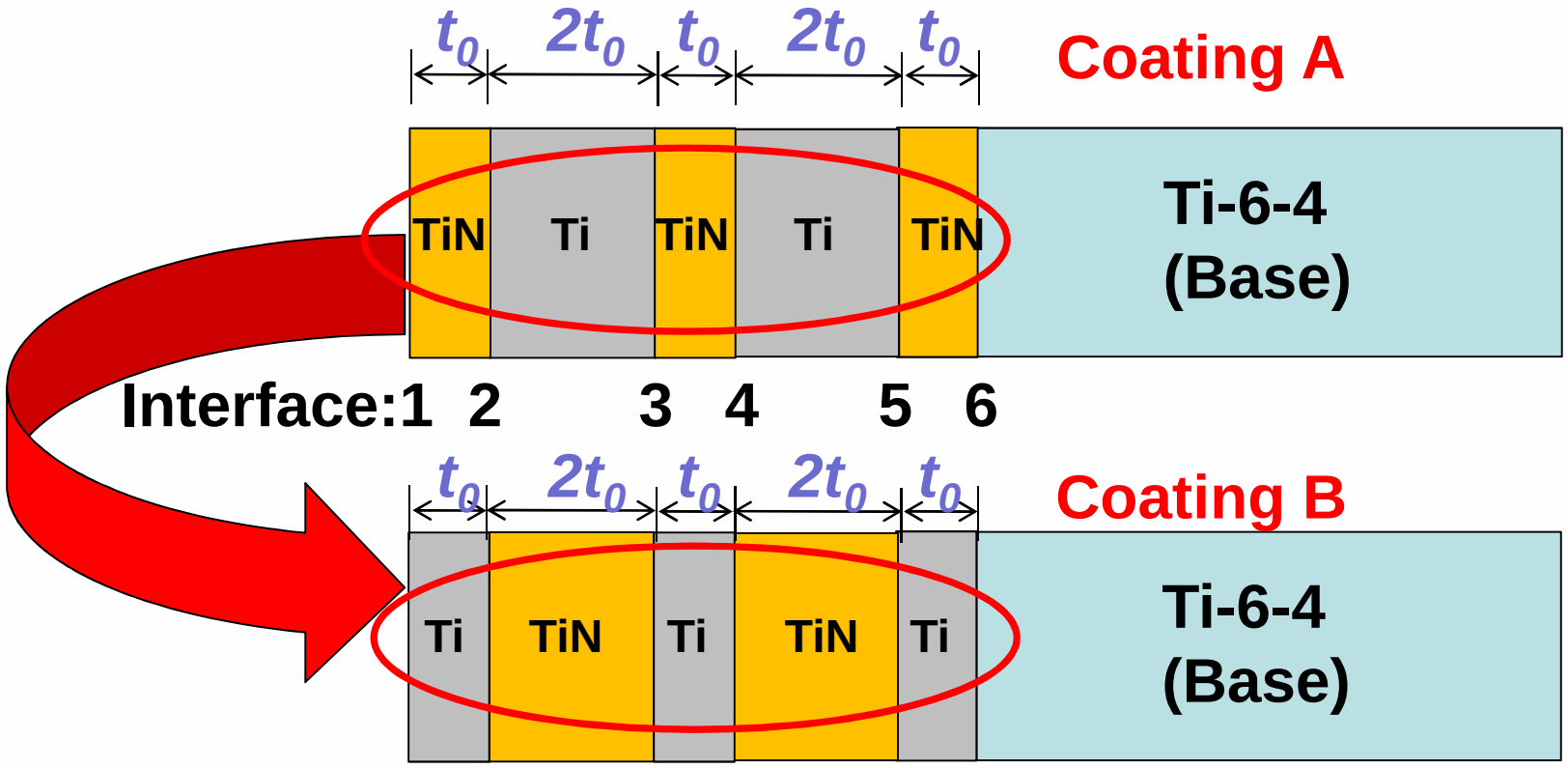






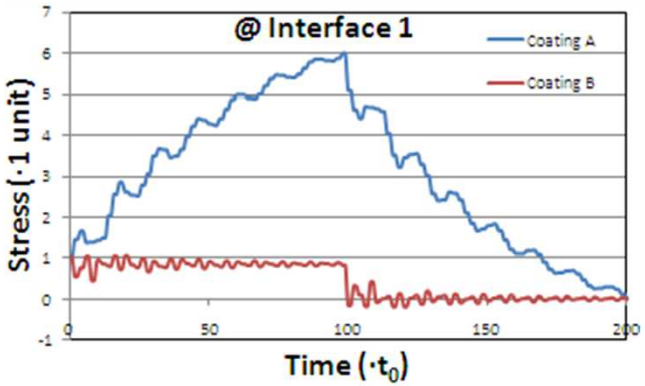
Coating A Vs. Coating B

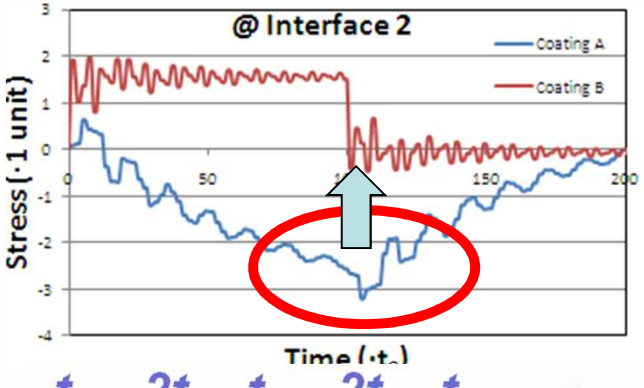
Time the wave travel through each layer

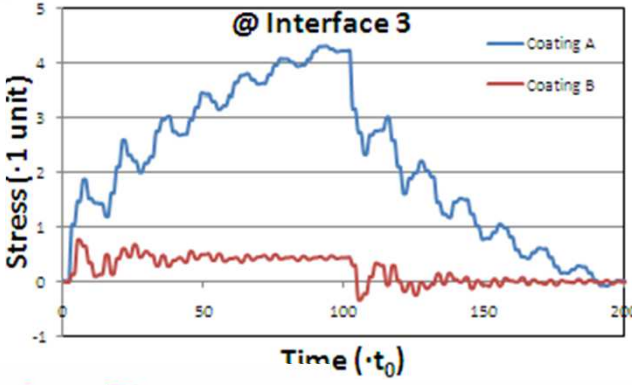


2 Calculated Results

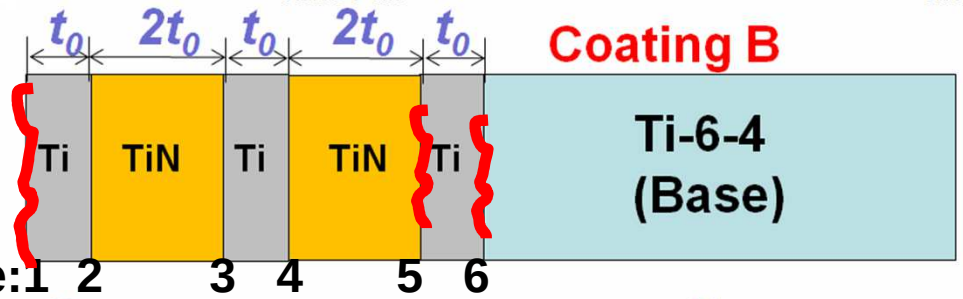
Coating A Vs. Coating B

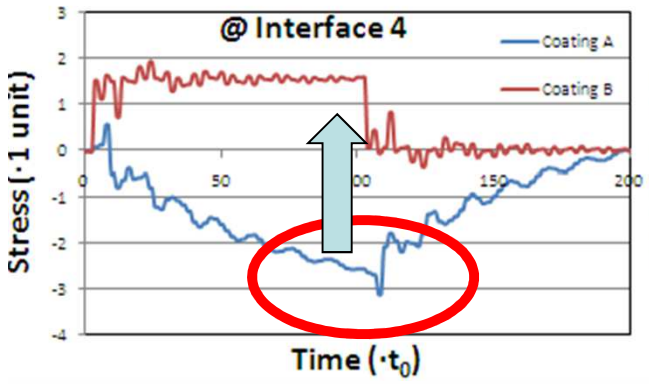


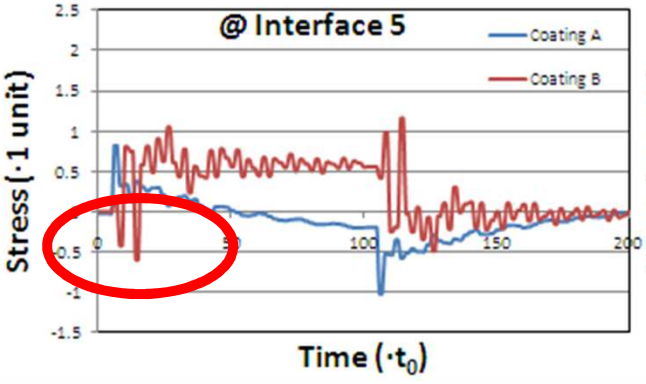


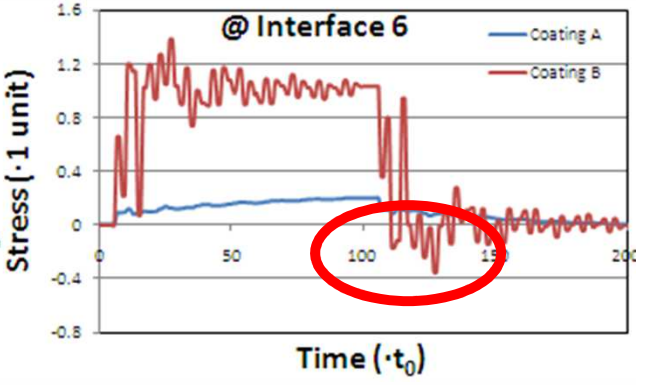


Better stress distribution
But weak surface



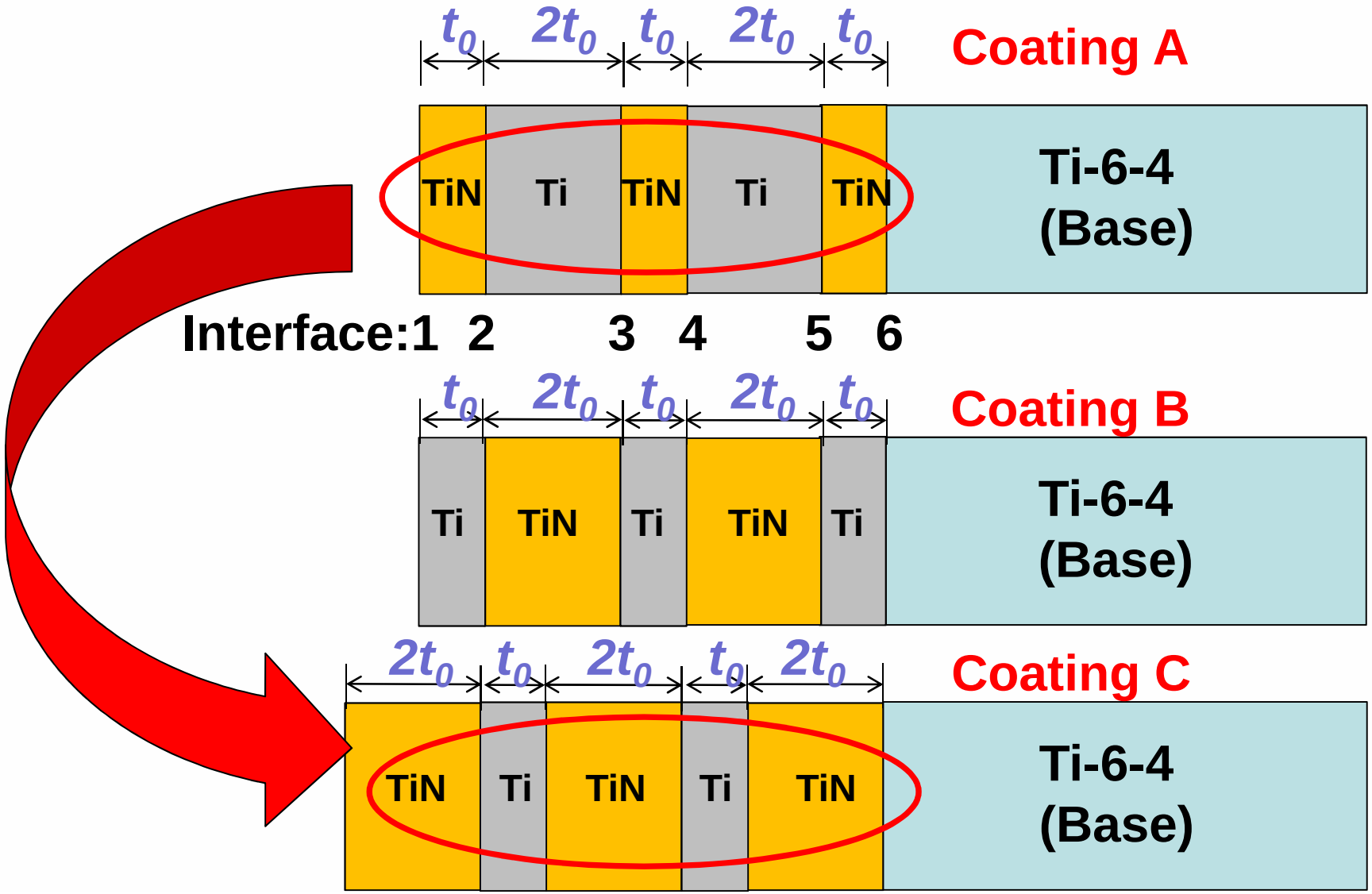






Coating A Vs. Coating C

Time the wave travel through each layer

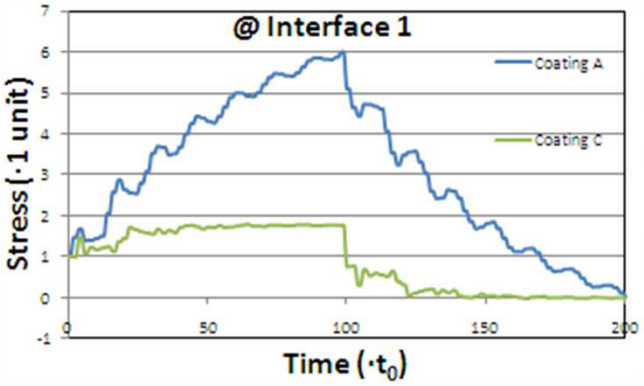


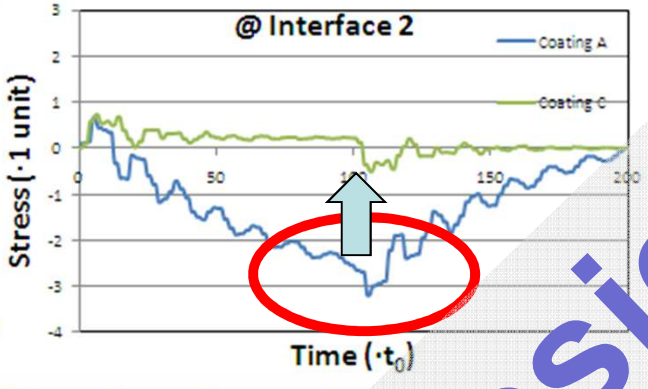
2

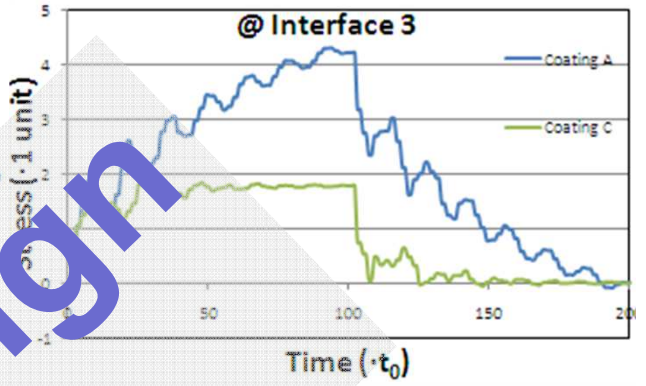
Calculated Results

Coating A Vs. Coating C

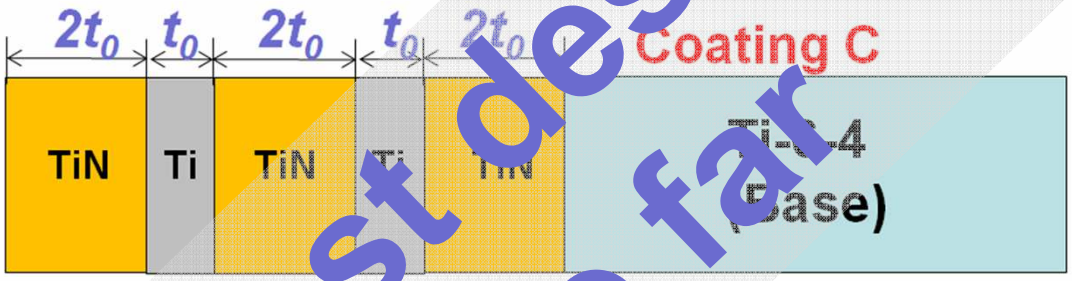
Coating C → No tensile stress @ any interfaces



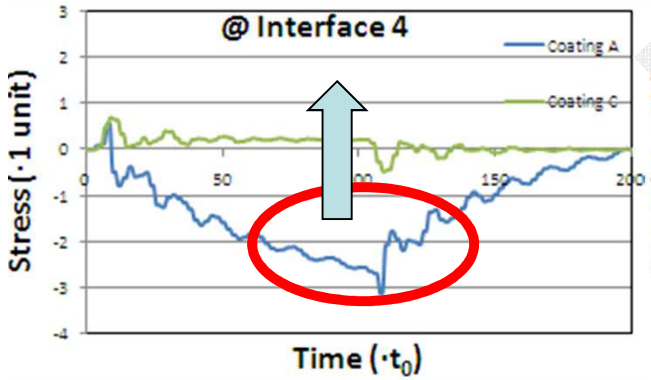


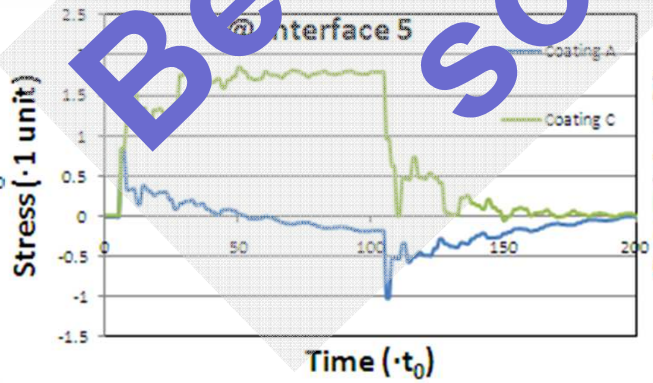


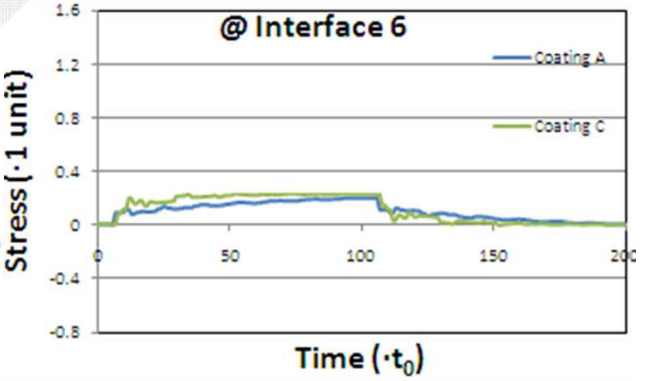
Best stress distribution & hard surface



Interface:1

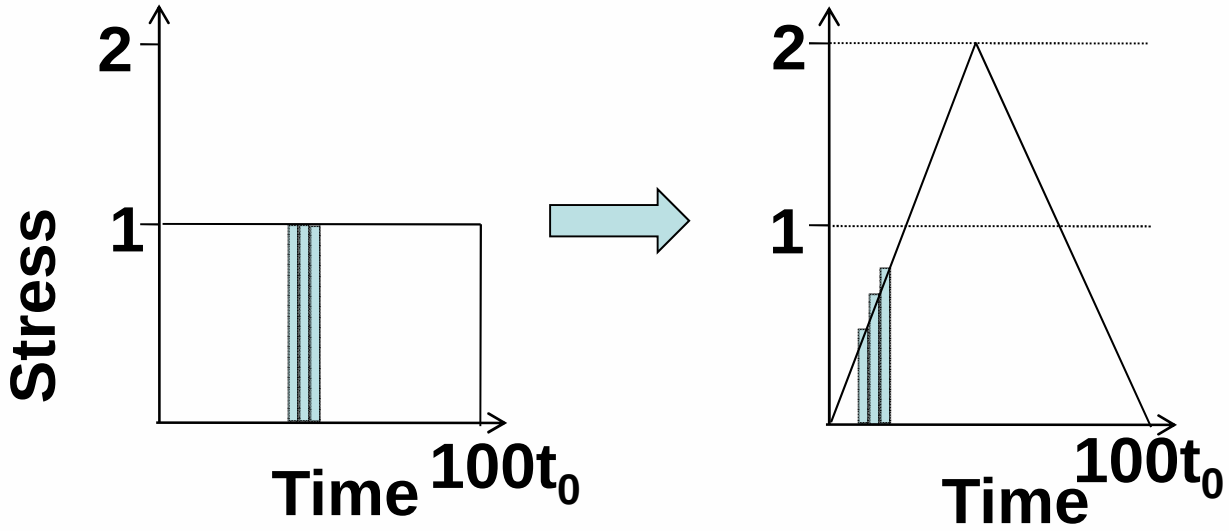




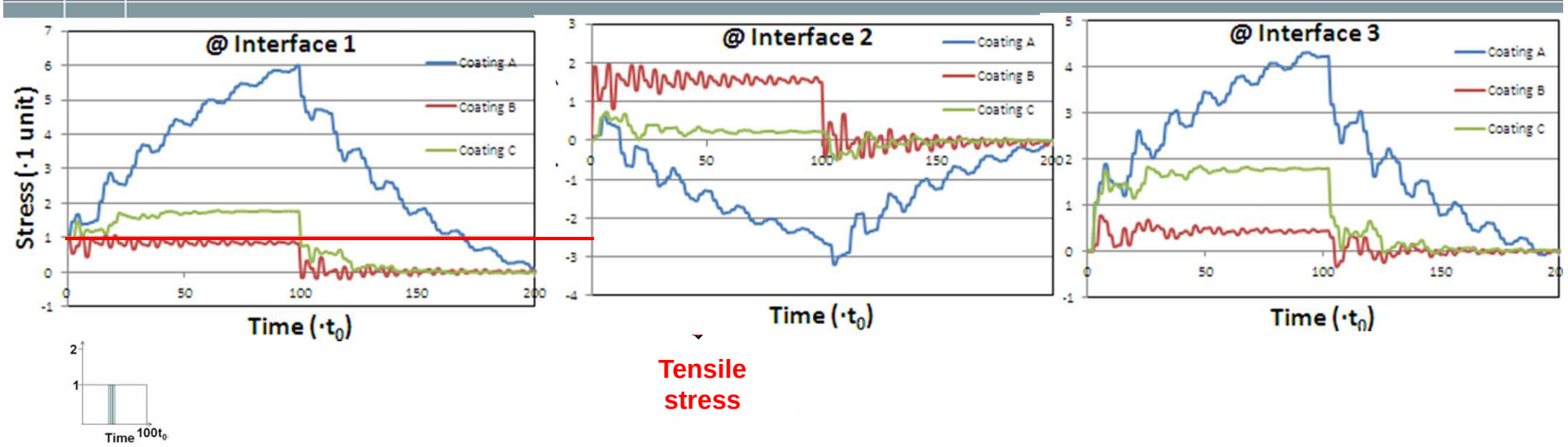


Best design so far

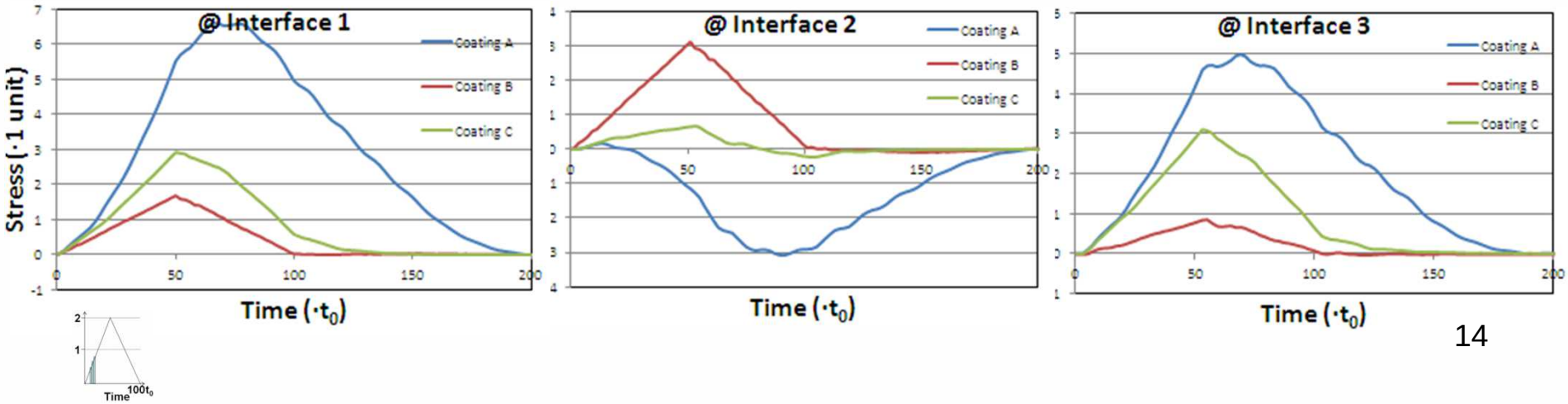
From Rectangle to Triangle Wave



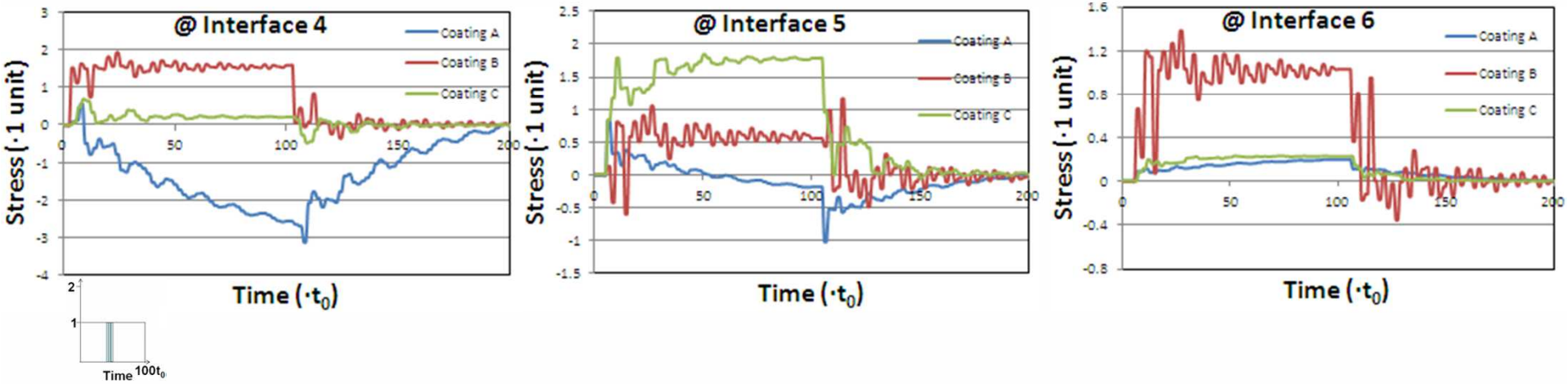
2 Calculated Results

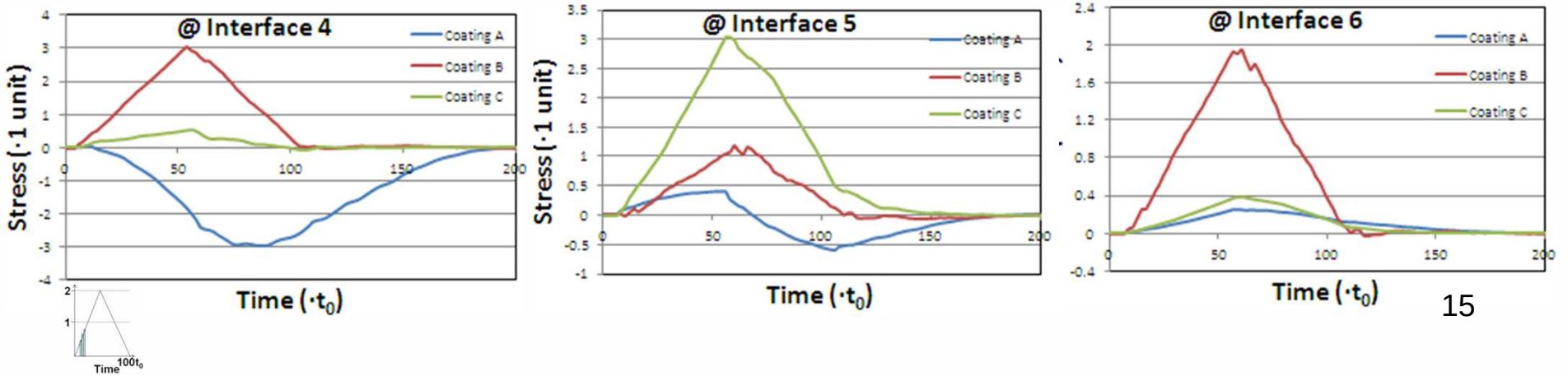


Tensile stress



2 Calculated Results





3 Conclusions

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1. For the coating A, the stress at all the interfaces behaves either as maximum compressive stress or maximum tensile stress. Through changing the thickness combination and/or changing the stacking sequence of layers, the stress at all the interfaces behaves can be changed to moderate compressive stress, which indicates an optimized stress distribution.

2. Potentially, the present work will be of help to better understand the droplet impingement on multilayer coatings, and give guidance in the design of multilayer coatings.

3 Conclusions

3. Limitation

Assumption:

* The impact occurs in one point.
* Single droplet.
* Same impact point.

Reality:

* Round area.
* Different droplets.
* Different time.
* Different places.

4. Future Work

Improvement of the current model, by taking into consideration:

* Diameter of the droplet.
* The time domain.

Thank You !