Effect of the CVD parameters on the fiber tensile strength of carbon fibers using single-fiber tensile test after carbon nanotubes growth

Dr. Evaldo José Corat
Lays D. Ribeiro Cardoso
Marinés C. Bravo Carvajal

São José dos Campos
2015
SUMMARY

➤ MOTIVATION

➤ INTRODUCTION
  • Carbon Nanotubes Growth models
  • Fuzzy Fiber
  • Nanostitching

➤ CARBON NANOTUBES PRODUCTION

➤ SINGLE FIBER TENSILE STRENGTH TEST

➤ RESULTS
  • SEM – FEG images
  • Weibull distribution
Motivation

- **50%** Advanced Composites
- **20%** Aluminum
- **15%** Titanium
- **10%** Steel (primarily landing gear)
- **5%** Other

How composite solutions are applied throughout the 787.
Introduction

Single Wall Carbon Nanotube (\textit{SWCNT})

Multi Wall Carbon Nanotube (\textit{MWCNT})
Carbon Nanotubes Growth Models

- Depends on the catalytic nanoparticle adhesion
  - growth via tip
  - growth via root
Steps needed to CNTs perfect growth on CF surface

- Si acts as a diffusion barrier to catalytic particles

* Reference [1]
CNTs grown on CF surface after Si deposition

Homogeneous CNTs growth
**Objective**

- Grown CNTs on CF surface to reinforce the interlaminar shear strength

*Reference [2]*
**Fuzzy Fiber**

CNTs are grown radially on CF surface

*Reference [3]*
• Nanostitching

Transfer the CNTs grown on a plane substrates to prepregs CF cloth

✓ Company from MIT that produces nanostitchings: N12 Technologies

* Reference [2]
Experimental Procedure
CNTs growth reactor

Evaporation

Deposition

Gas flow

Sample insertion
Depositon Fixed Parameters

Precursor Solution

Hexane + Ferrocene (Saturated Solution)

- Solution evaporation temperature: 200 °C

- Dripping flow
  - ~0.2 mL / 30 sec

- Gas flow
  - Ar: 100 sccm
  - C₂H₂: 5 sccm
  - CO₂: 5 sccm

- Pressure: ~1 atm
Varied Parameters

- **Sample**
  - ✓ CF unsized (Toho HTS45, 12k, 7 μm)
  - □ Unsizing
    - • 450 °C
    - • 15 min.
    - • Ar flow: 300 sccm

- **Exposure Time**
  - ✓ 1 min
  - ✓ 5 min
  - ✓ 15 min
  - ✓ 30 min

- **Heating/Growth Temperature**
  - ✓ 650 °C
  - ✓ 800 °C

*Note ➔ + 1 min heating after the heating/growth process.
Single Fiber Tensile Test

- **CETR Tribometer**

- **Parameters**
  - Load Cell: 500 mN
  - Velocity: 0.008 mm/s
  - Time: ~60 sec
  - Specimen: 2.5 cm
  - ASTM C1557-14 [4]
Results and discussion
✓ CNTs deposition at 650 °C during 5 min.
CNTs deposition at 800 °C during 5 min.
Weibull Distribution

➢ Heating at 650 °C
➢ Heating at 800 °C
After CNTs growth at 650 °C
After CNTs growth at 800 °C
Conclusions

- The SEM images shows that CNTs grows more efficiently at 650 °C, whilst at 800 °C diffusion process of the catalytic particles are activated and a homogeneous growth of CNTs is not achieved.

- The Weibull distribution showed temperature or exposure time does not influence the mechanical properties of the fiber.

- The Weibull distribution after the CNT growth process shows that at high temperature (800°C) the tensile strength decreased considerably compared to low temperatures (650°C) indicating degradation of the CF.
References


E-mail: evaldo.corat@inpe.br
Thank You!