Sorrento SAPEM'23 常熟

# Granular Activated Carbon Sound Absorption Calculation with Measured Particle Parameters

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Noise & Vib. Research

# PART 01

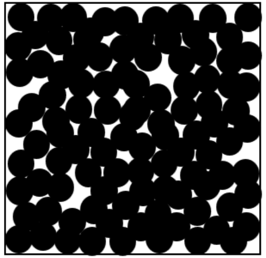
# Introduction

# Hierarchical Porous Particles

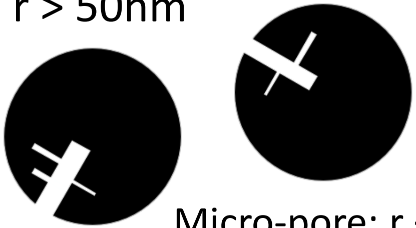
- Typical Hierarchical Porous Particle
  - Activated Carbon

  - Zeolite

  - Silica Gel

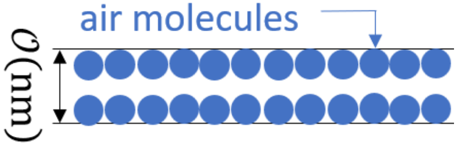


Macro-pore: r > 50nm



Micro-pore: r < 2nm

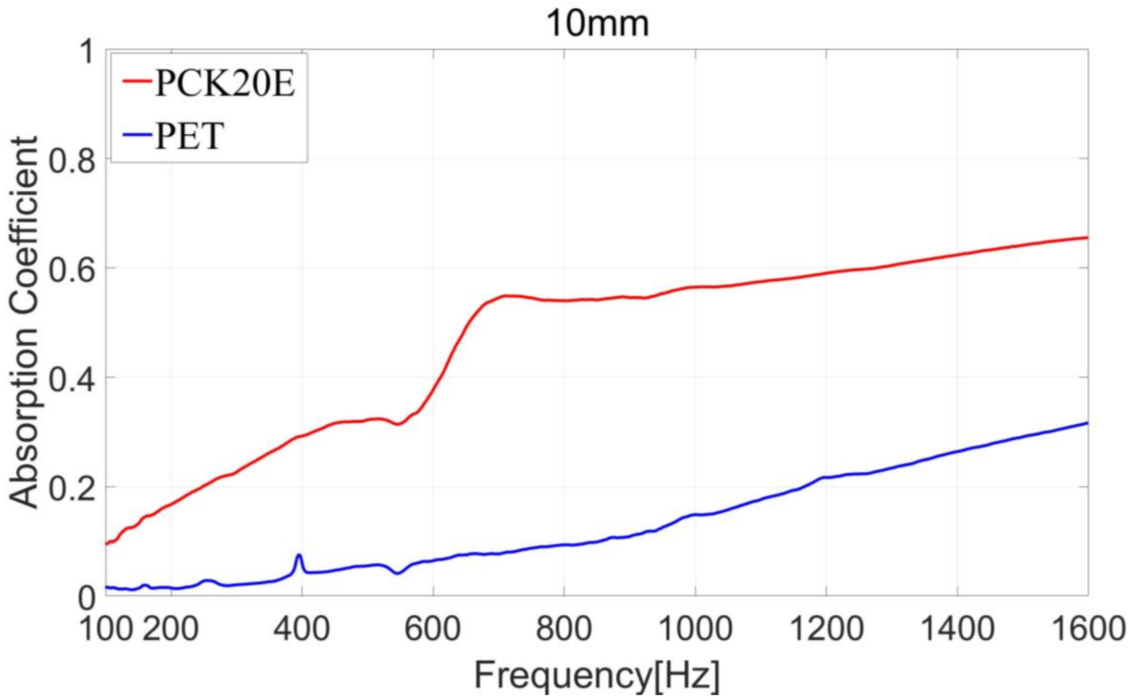
Meso-pore: 2nm < r < 50nm

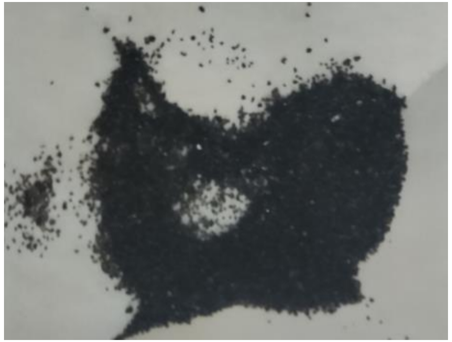


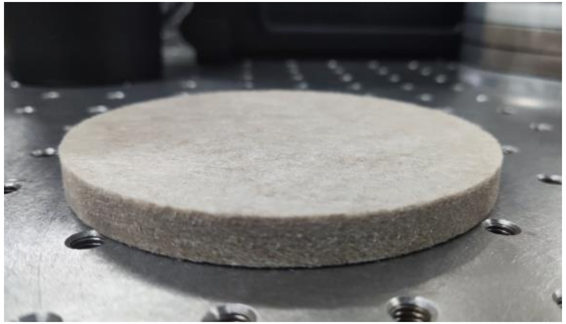

- Adsorption effect decreases the modulus of air, then slow down the speed of sound

# Sound Absorption Comparison

- Same thickness AC shows better sound absorption compared with fibrous material





# Rigid Granular Activated Carbon Model

$$\eta\nabla^2\mathbf{u} - \nabla p = j\omega\rho_0\mathbf{u}$$ conservation of momentum

$$\kappa\nabla^2\tau + j\omega p = j\omega\rho_0 C_p\tau$$ conservation of energy

$$pP_0^{-1} = \tau\tau_0^{-1} + \rho\rho_0^{-1}$$ state equation

$$j\omega(\rho + \rho_a) + \rho_0\nabla\cdot\mathbf{u} = 0$$ conservation of mass

$$\mathbf{u} = -c_v l_{\text{mean}}(\mathbf{t}_1\cdot(\nabla\mathbf{u})\cdot\mathbf{n})\mathbf{t}_1 \ \text{on}\Gamma_s$$ Slip boundary condition

$$\tau = 2c_t\gamma(\gamma+1)^{-1}\Pr^{-1} l_{\text{mean}}(\nabla\tau\cdot\mathbf{n}) \ \text{on}\Gamma_s$$ temperature jump boundary condition

$$\rho_a = k_a k_d \rho_N \omega_a^{-1}(j\omega + \omega_a)^{-1} p$$ Langmuir model

$$\frac{j\omega p^{(0)}}{E(\omega,\text{Kn},k_a,k_d)} = \nabla_x\cdot\left(\frac{\mathbf{k}(\omega,\text{Kn})}{\eta}\nabla_x p^{(0)}\right)$$

# Model Input Parameters

| | |
|---|---|
| $\phi_p$ | Inter-particle porosity |
| $r_p$ [mm] | Particle radius |
| $\phi_m$ | Meso-pore porosity |
| $r_m$ [$\mu$m] | Meso-pore radius |
| $\phi_n$ | Micro-pore porosity |
| $r_n$ [nm] | Micro-pore radius |
| $b \times 10^6$ [1/Pa] | Langmuir constant |

Part of the parameters are from inverse fitting

1.Can we get those parameter directly?

2.Design the particle for better acoustics performance

# PART 02

# Material Parameter Measurement

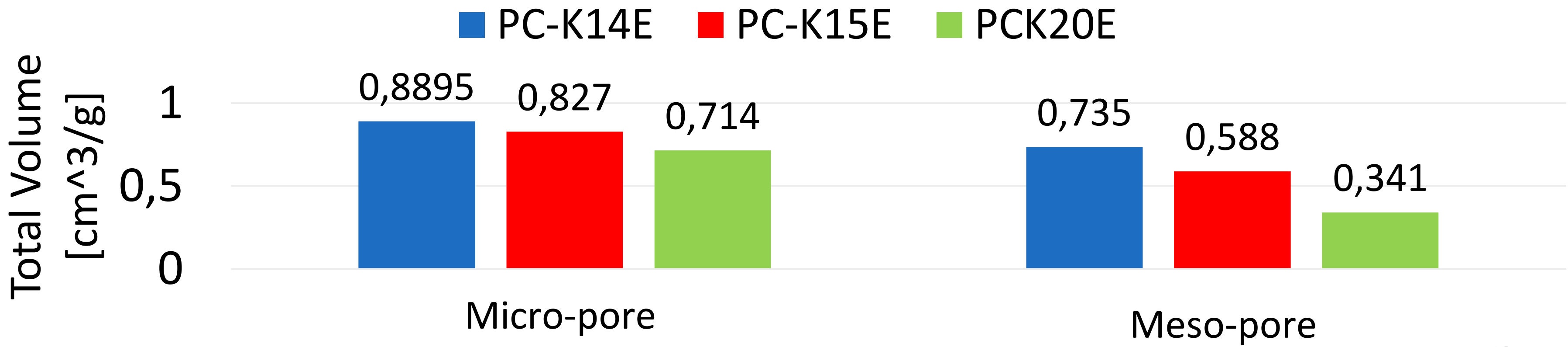
# Pore Size Analyzer


77K isothermal adsorption measurement

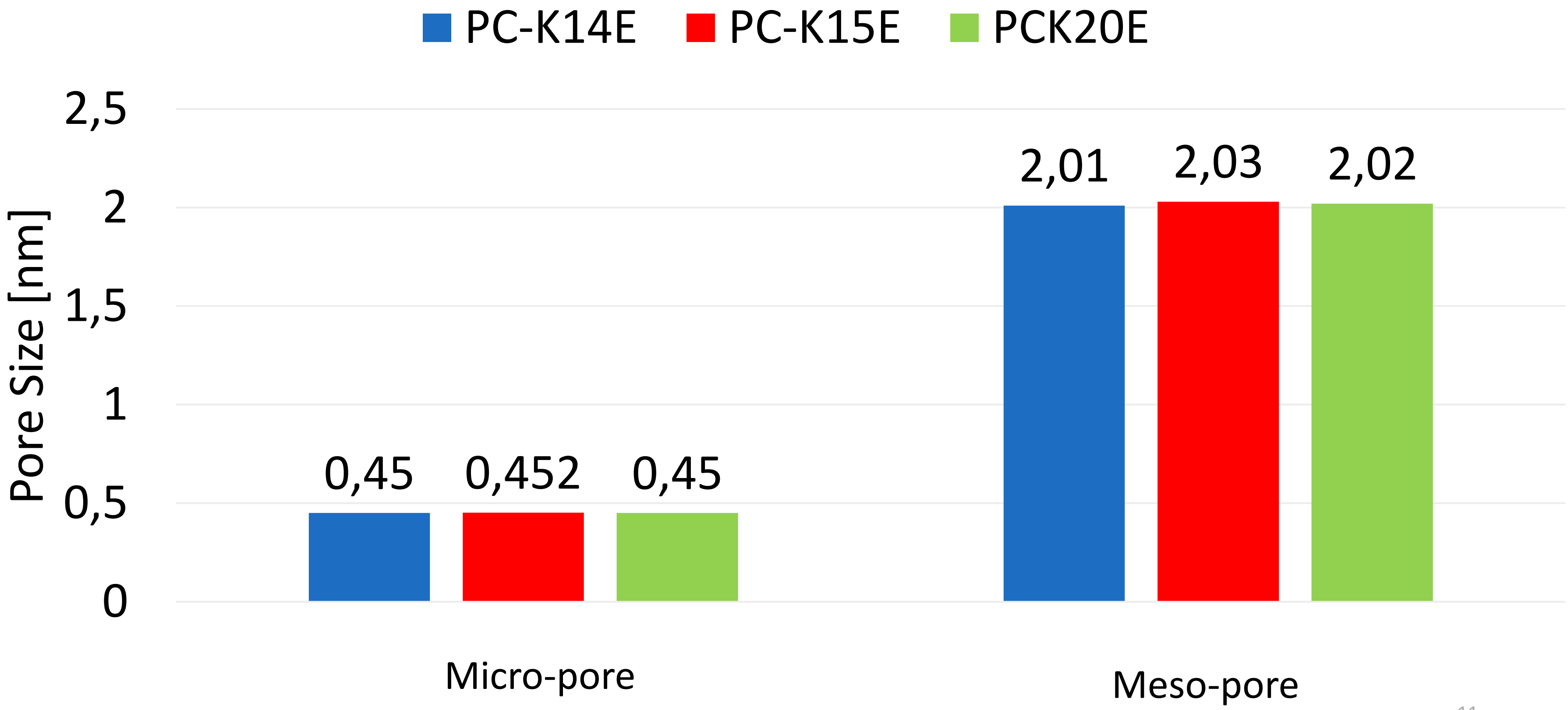
- BJH method
  - Meso-pore size distribution
  - Meso-pore volume distribution
- HK method
  - Micro-pore size distribution
  - Micro-pore volume distribution

# Pore Volume Comparison

| | PC-K14E | PC-K15E | PC-K20E |
|---|---|---|---|
| Particle Size [μm] | [300,600] | [300,600] | [300,600] |



# Pore Size Comparison



# Langmuir Constant

- Langmuir Model

$$\frac{n}{m} = \frac{bP}{1+bP}$$

$$b = b_0 \exp(-\Delta H \;/\; RT)$$

m: Single layer max absorption

$\Delta H$: average adsorption heat

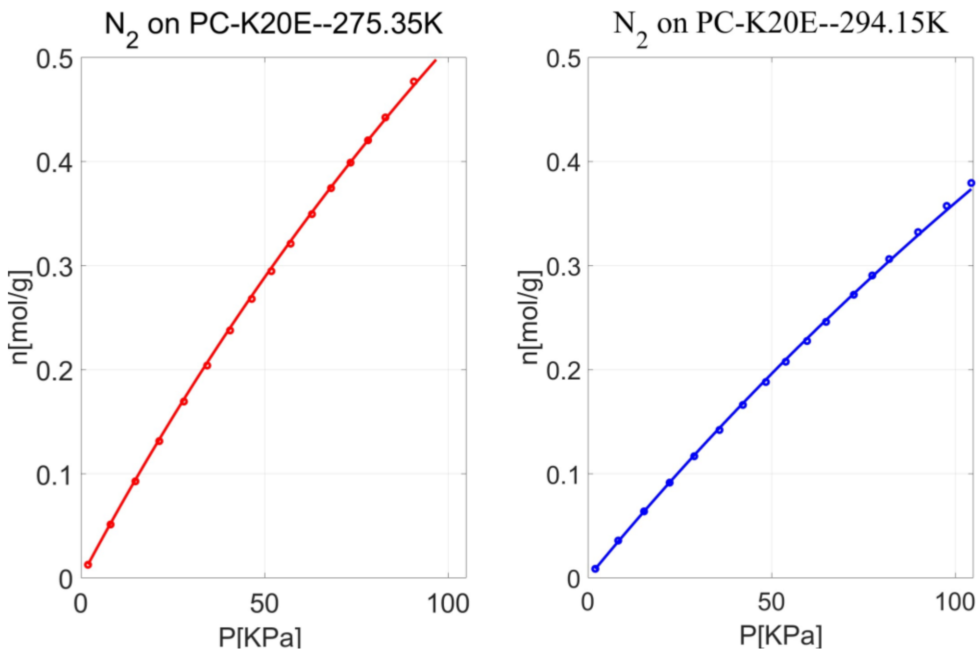
n: absorption amount P: pressure

T: temperature

Instrument measures Langmuir Constant at 77K

↓

Measure isothermal adsorption curve at 20C and 0C



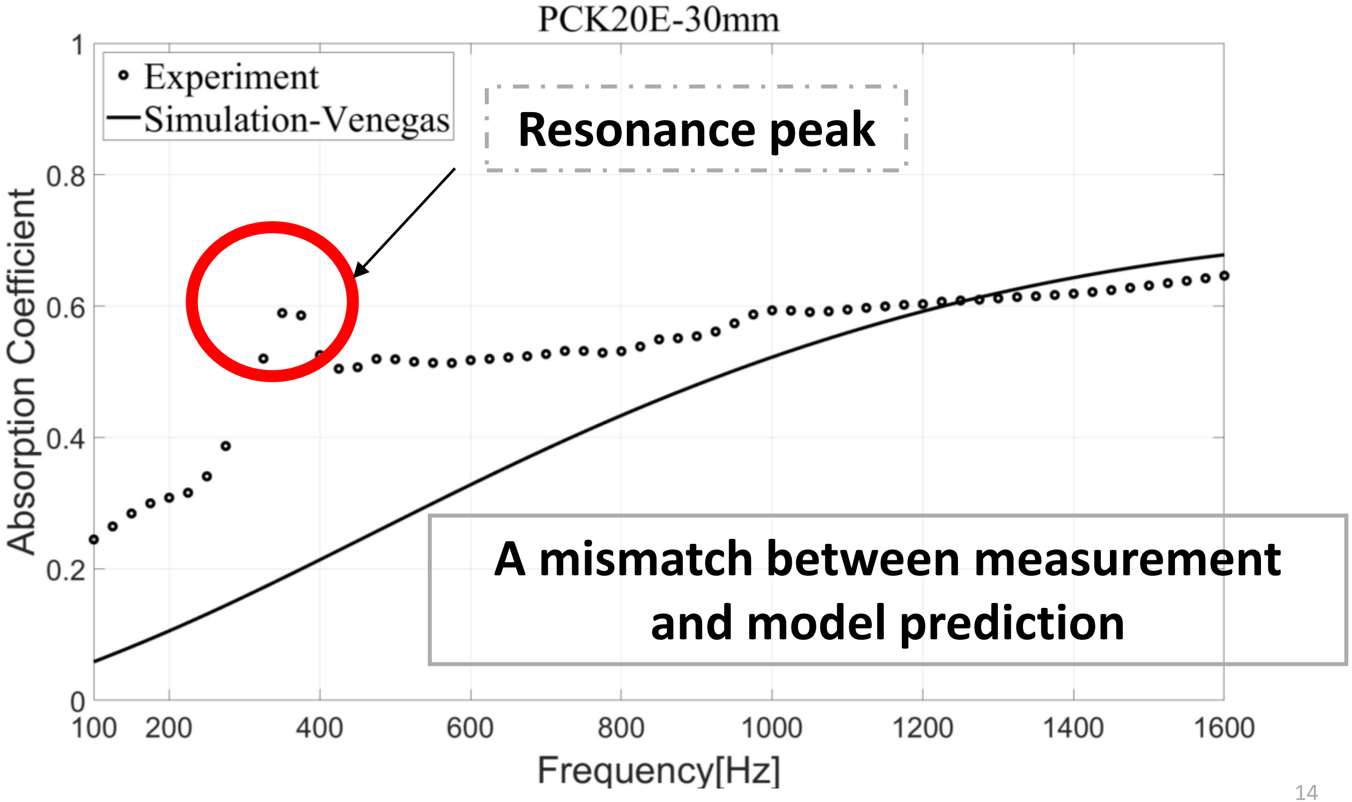

| $\Delta H$[KJ/mol] | b0[1/Pa] | b[1/Pa] |
|---|---|---|
| -15.52 | 3.4e-06 | 1.9e-06 |

# PART 03

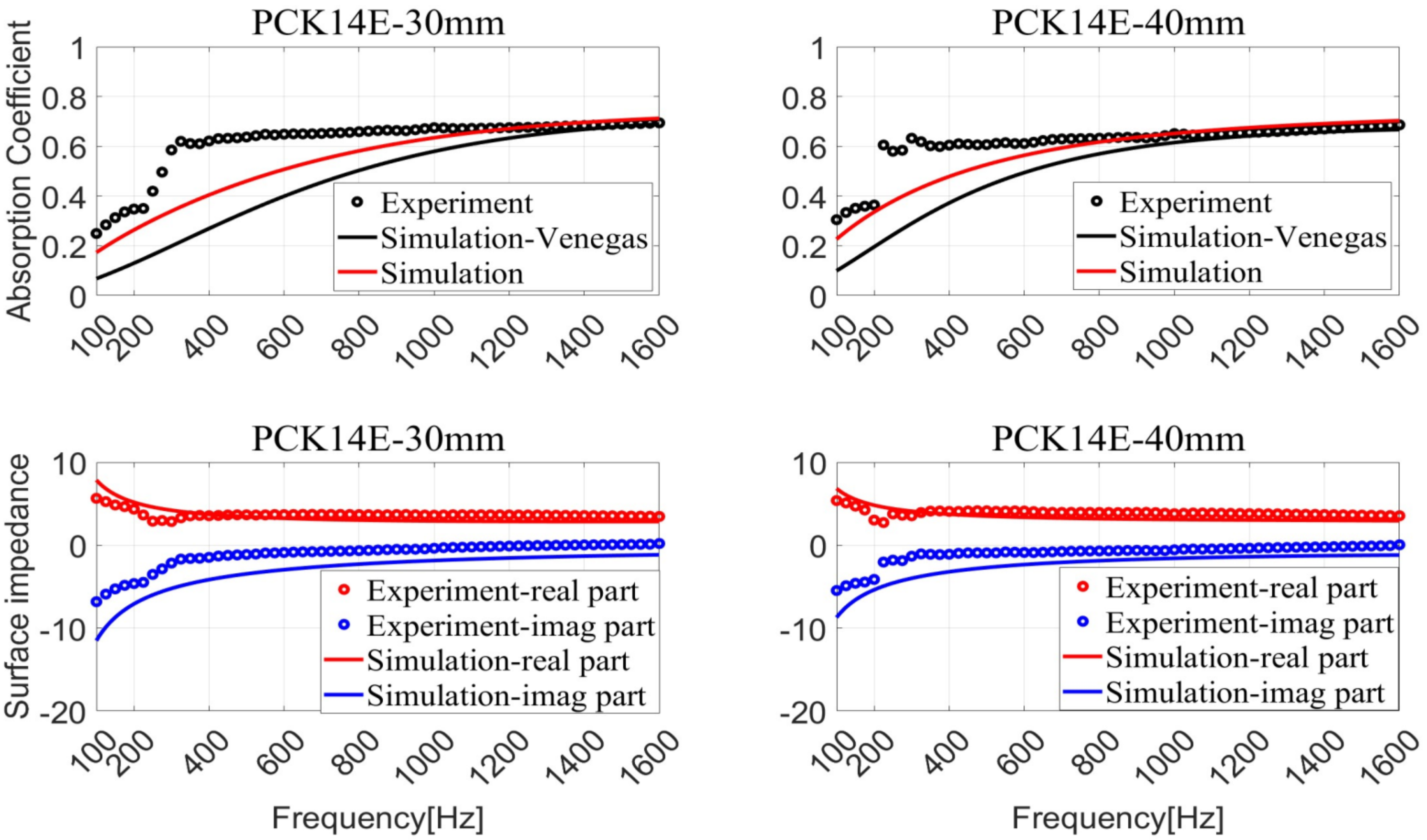
# Acoustics Measurement

# E-1050 Measurement

- Measurement Set-up



# Introduce Adsorption Effect Into Meso-Scale



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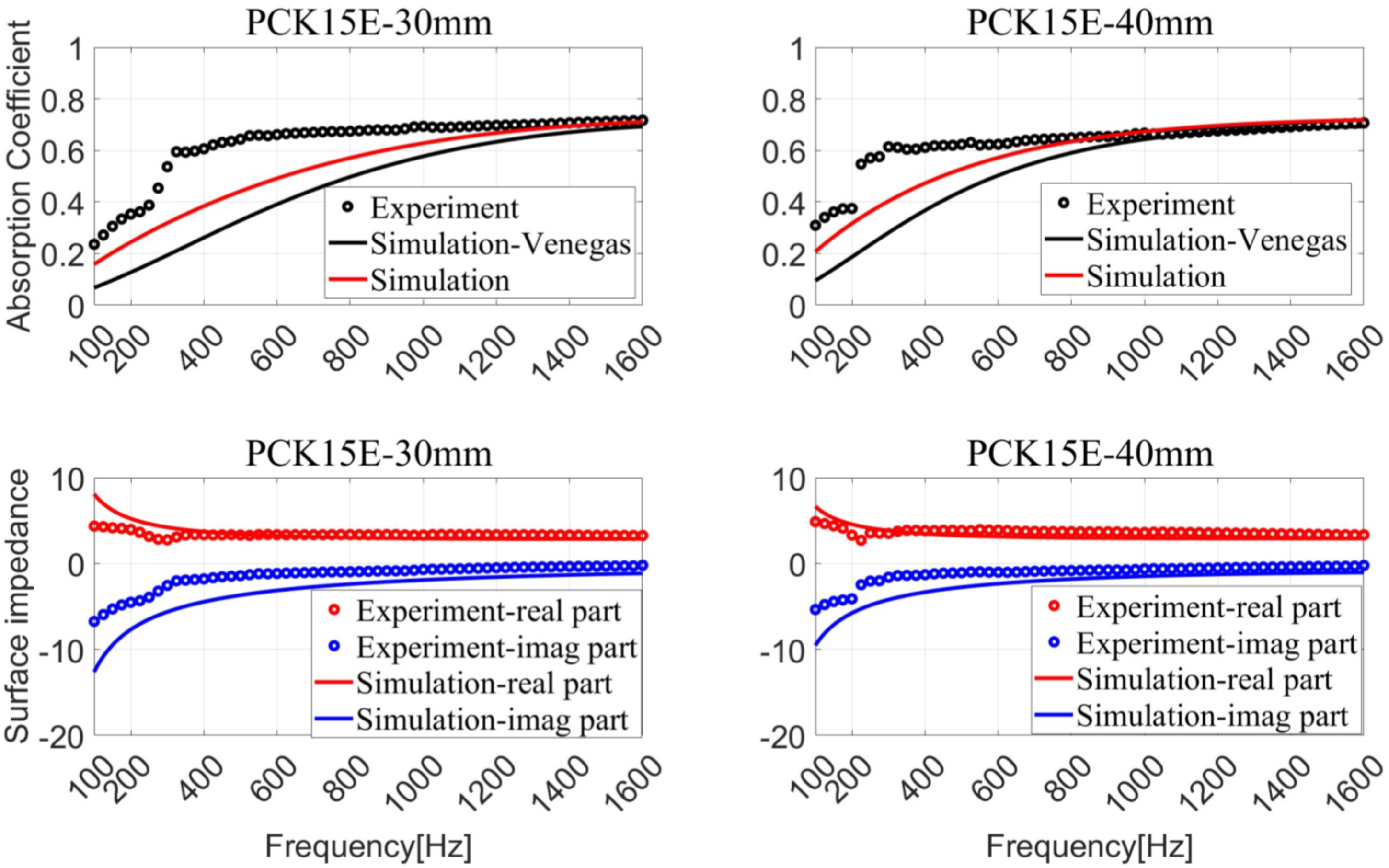

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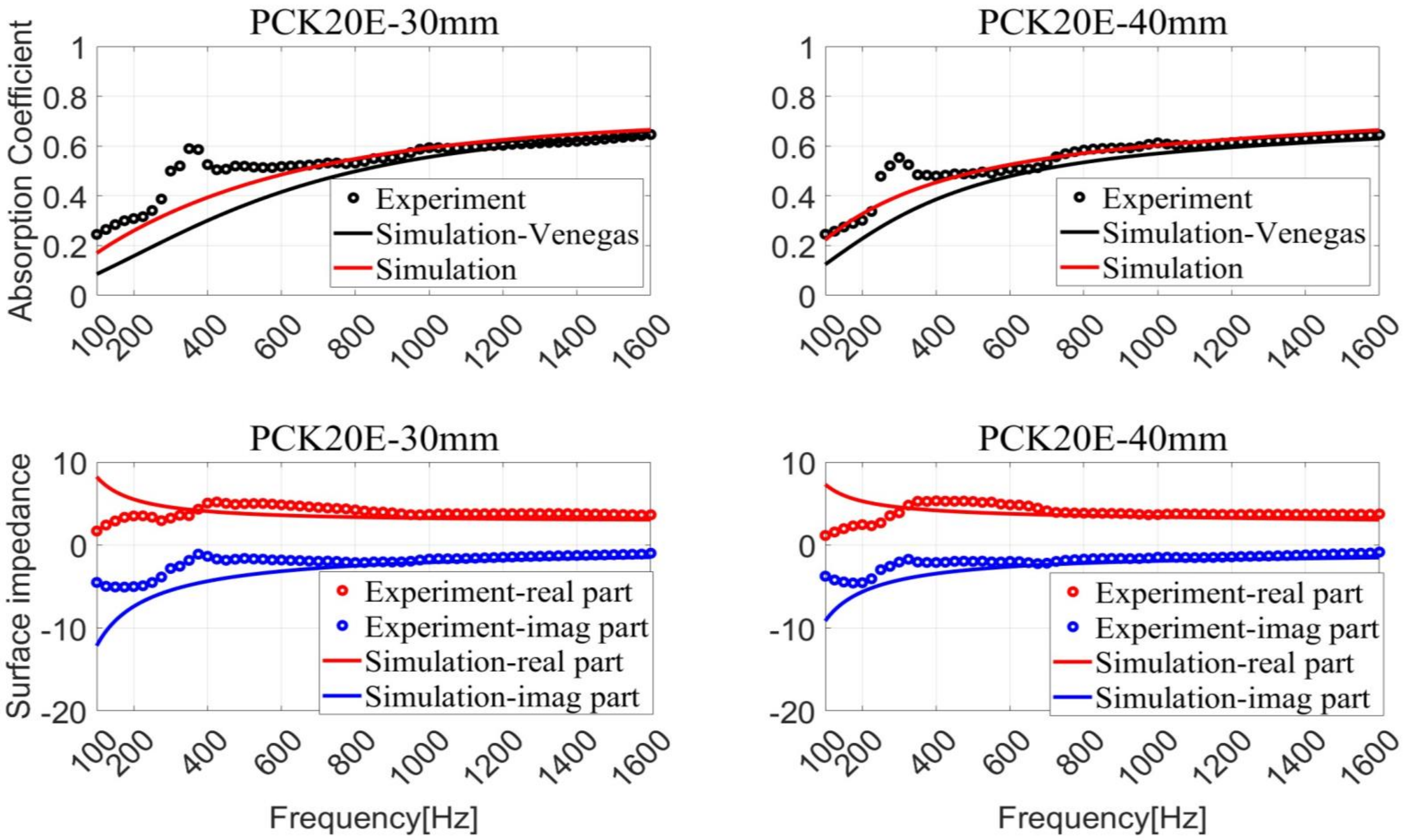

# PART 04

# Conclusion

# Conclusion

**A 2DFD model was built to simulate the performance of absorbers consisting of membrane and porous granules:**

1. **The comparison between the 2DFD simulation and 1D analytical model prediction shows that it is necessary to consider the modal response in the radial direction when separation between membrane and granules is small**

2. **The simulation shows potential advantages of bringing the granules close to the membrane, where the interaction of the membrane nearfield and the granule stack may be exploited to increase energy dissipation and to reduce reflection**

3. **The simulation of the absorber with a perforated membrane shows more dramatic improvement at low frequencies when GAC is added to the absorber**

**In the future, it is of interest to experimentally validate the predictions of the 2DFD model, and find theoretical explanation of the difference with the 1D model prediction, especially when the air gap is narrow**

Thanks for your attention!